A Summary of Current Program, 7/1/62

and Preliminary Report of Progress

for 10/1/60 to 6/30/62

ENTOMOLOGY RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Section A

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between October 1, 1960 and June 30, 1962. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
July 1, 1962

TABLE OF CONTENTS

INTRODUCTION

Entomology research is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugar beets, and ornamental crops; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many kinds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at 4 billion dollars annually.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits

to provide specific methods of control for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has work located at 65 field locations in the United States, 4 locations in foreign countries, and one in Guam. Of the total professional staff of 424, 122 are located at the Agricultural Research Center, Beltsville, Md., or at Washington, D. C. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Department of Defense, Department of Health, Education, and Welfare, Department of Interior, World Health Organization, and Agency for International Development.

A broad analysis of the Division's research by different approaches to insect control shows that about 33 percent of the current effort is on the conventional chemical approach to insect control; 12 percent on biological control (parasites, predators, and pathogens); 5 percent on plant resistance to insects; 14 percent on the sterility and other new approaches to insect control such as natural attractants; and 36 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases. Substantial changes in the research effort have been made in the last 5 years, largely by shifts within available funds, to place more emphasis on non-chemical or on special chemical approaches to insect control.

The following examples of outstanding achievements in research by scientists in the Entomology Research Division illustrate the value of entomological research in the improvement of the Nation's agricultural economy and general welfare of the people:

Plant varieties resistant to insect attack. Although only limited effort has been devoted to the development of plant varieties resistant to insect attack, excellent progress has been made in dealing with several important insect problems by this desirable control method. Seventeen varieties of wheat that possess resistance to the hessian fly, a long-time serious pest of wheat, have been developed as a result of cooperative efforts of Federal and State entomologists and plant breeders. These varieties have been released to the growers by State Experiment Stations in cooperation with the U. S. Department of Agriculture. Nine of the resistant varieties were released in 1960-62. Today hessian fly-resistant wheats are being grown on more than 4,500,000 acres of winter wheat. As a result this formerly major pest has been relegated to the status of a minor pest of wheat. Plant breeders and entomologists working together have made rapid progress in the development of varieties of alfalfa highly resistant to the spotted alfalfa aphid, an important pest accidentally introduced into the United States in 1954. After only a few years of research, four varieties--Lahontan, Moapa, Zia, and Cody--each adapted to particular areas, are now being grown in the Western States.

Attractants, baits, and sterilants for fruit fly control. Fruit flies constitute the most important insect threats to our tropical fruit industries. Research in Hawaii and Mexico has led to major advances in methods for controlling or eradicating these pests. Several outstanding lures, including methyl eugenol, trimedlure and cue-lure, have been developed which attract males of the oriental, Mediterranean and melon fly, and are of vital importance in early detection of infestations and are potentially useful in control. In addition, work on attractants for baits has led to the protein hydrolysate-malathion bait spray which was used for eradicating the Mediterranean fruit fly in Florida in 1957 and again in 1962. Research in progress shows promise in the possible utilization of the sterility method for fruit fly eradication. Investigations on this procedure involves both atomic radiation and new insect sterility-producing chemicals.

Sex attractants--a new approach to insect control. The isolation, identification and synthesis of the powerful sex attractant found in gypsy moth females represents a break-through in research on the development of highly specific methods for insect detection and opens the way for a new desirable approach to insect control. Recent research has shown that virgin female adults of several major pests, including the pink bollworm, tobacco hornworm, cockroaches, peach tree borer, and banded cucumber beetle, contain specific sex

attractants. Research on methods of isolation and on the chemical composition of the natural attractant substances are underway with a view to their future synthesis.

Insect control in relation to human health. Department entomologists and chemists, since World War II, have carried out research for the Department of Defense on pests and insect vectors of diseases of concern to our military personnel. Outstanding contributions have been made in the development of ways to control insect vectors of major diseases which have not only been important to our national defense but of great benefit to human welfare. The residual insecticide method of malaria control used by health agencies throughout the world is based on original research of ARS scientists. All of the insecticides used for controlling lice that transmit the serious typhus disease were also developed by them, as well as new insect and mite repellents that are used by both military personnel and civilians as a means of personal protection from pests and disease carriers.

Sterility method of insect control. A new concept in controlling insects and other pests has been developed which may contribute to the solution of some major insect problems. The method involves the release of sterile insects for their own destruction. The mass production and release of screw-worm flies made sterile by gamma radiation resulted in the elimination of this important livestock pest from the Southeast. A similar and more complex program based on the same principle is now underway in the Southwest. In addition, the utilization of sterile insects is being intensively investigated as an aid to the control or eradication of other major pests, including tropical fruit flies, boll weevil, pink bollworm, sugarcane borer, codling moth, tobacco hornworm, and other pests. An important advance in research on the sterility method has been the development of several chemicals which produce sterility in insects with less damage to the insects than that caused by radiation. The availability of such chemicals also offers the possibility of discovering ways to induce sterility in the natural insect population, thus obviating the necessity of rearing and releasing insects sterilized by radiation to achieve control.

* * * * * * * *

In this report, there is presented a description of the Division's program as of July 1, 1962, and a summary of progress for the period October 1, 1960, through June 30, 1962. The Research and Marketing Advisory Committees, in their meetings during fiscal year 1962, devoted their attention to a review of the research program of the Department. Hence this report provides information on progress to cover the period since the last report on progress to the Committees.

AREA 1. VEGETABLE INSECTS

Problem. Insects and mites are important limiting factors in the production of high-quality vegetables. They reduce the yield, lower the quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. The use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating milk and meat by feeding crop refuse or byproducts of peas, beans, or other vegetables treated with insecticides. The drift of certain insecticides into other fields or areas can also cause problems. Another difficulty is that a number of vegetable insects have developed resistance to certain insecticides. For many vegetable insects there is an increasing need for safe, effective, and economical methods of control that will not leave harmful residues on the marketable produce or adversely affect the flavor or quality. Research is needed on methods for better utilization of predators, parasites and insect diseases of vegetable insects; the development of varieties of vegetables resistant to insect attack; the development and utilization of more effective traps and lures; an exploration of new approaches to control including radiation, chemosterilants, and antimetabolites; and an evaluation of application equipment. Such developments would help decrease the necessity for employing hazardous chemicals. Better methods are required to forecast insect damage before it occurs, and to determine when it will be profitable for growers to apply control measures.

USDA PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz.; Riverside, Calif.; Tifton, Ga.; Twin Falls, Idaho; West Lafayette, Ind.; Beltsville, Md.; State College, Miss.; Forest Grove, Oreg.; Charleston, S.C.; Logan, Utah; and Walla Walla and Yakima, Wash., in cooperation with the respective State Experiment Stations and industry. The work is also cooperative with the Idaho Bean Commission, the Louisiana Agricultural Experiment Station, and the following ARS Divisions: Northern Utilization Research and Development, Crops Research, Pesticides Regulation, Agricultural Engineering Research, and Human Nutrition Research. All of the work in Oregon is conducted jointly with the Agricultural Engineering Research Division.

The major objective of this work is to develop more effective and economical and less objectionable methods of controlling insect pests of vegetables in the field to reduce losses from these pests without leaving undesirable insecticide residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, and without adversely affecting beneficial insects. Increased emphasis has been given to new approaches to insect control. It is necessary to learn more about the biology and habits of the pest insects with the object of developing methods of controlling them without using insecticides. A widespread search is in progress for sex lures that can be utilized in insect detection and control, requiring a much better knowledge of mating habits of the various insect species. Also underway are studies of male sterilization techniques for such insects as Drosophila and the Mexican bean beetle by means of gamma radiation and chemical sterilant techniques that may permit insect control on an area basis. Investigations were also initiated on the banded cucumber beetle as a pest of sweetpotato in South Carolina and Louisiana. The work in Louisiana is under contract with the Louisiana State Experiment Station.

The Federal scientific effort devoted to research in this area totals 28.2 professional man-years. Of this number 2.8 is devoted to basic biology, physiology and nutrition; 5.5 to insecticidal and cultural control; 5.7 to insecticide residue determinations; 3.2 to biological control; 3.2 to insect sterility, attractants and other new approaches to control; 2.2 to evaluation of equipment for insect detection and control; 1.9 to varietal evaluation for insect resistance; 2.2 to insect vectors of diseases and 1.5 to program leadership. The Fort Collins, Colo., station was closed in January 1962 and the funds and personnel transferred to Yakima, Wash. This consolidation of work facilities involved only 0.7 professional man-years of work on vegetables which will be reduced to 0.3 in order to increase research on control of aphids as vectors of virus yellows diseases of sugar beets in response to urgent requests from industry and growers for assistance.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 47.3 professional man-years on research on vegetable insects divided among subheadings as follows: Basic biology, physiology and nutrition 7.5; insecticidal and cultural control 20.5; insecticide residues 8.9; biological control 2.0; insect sterility, attractants and other new approaches to insect control 1.1; evaluation of equipment for insect detection and control 1.6; varietal evaluation for insect resistance 1.5; and insect vectors of diseases 4.2. This work is being done in 39 States and about 25% of it is

concentrated in California and Florida. California is doing notable work on the biological control of insects and North Carolina and Wisconsin on varietal resistance. State Experiment Stations in 25 States and the USDA cooperate in 5 regional projects (NC-19, NC-33, NE-36, S-22, and W-45) on pesticide residues.

Industry and other organizations. In addition to substantial contributions by industry on synthesis, analysis, formulation, and primary screening of insecticides for general use, which are discussed in another area, several chemical companies conduct extensive field tests of insecticides against insects and mites that attack vegetable crops. Some of these companies cooperate with growers in such research. Others have their own experimental plantings. The results of such work are often kept confidential. Many vegetable growers cooperate with USDA and State Experiment Stations in providing field plots in which insecticidal research may be conducted. These plots are usually provided at no expense and the grower takes care of all production practices except the control of insect pests. Exclusive of its contributions through grants to and cooperative agreements with State and Federal stations, industry contributes estimated annual expenditures equivalent to approximately 15 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Leaf Miners. A great deal of trouble has been experienced in identifying the leaf miners that have been so destructive to tomatoes, peppers, southern peas and other vegetables in Florida, Georgia, and South Carolina in recent years. Specialists in the National Museum consider them a new species of the genus Liriomyza. Similar trouble has been experienced with what has appeared to be another new species causing serious losses to greenhouse chrysanthemums in Maryland and Northeastern States grown from cuttings imported from the South and Southwest. The injury or mines on chrysanthemum leaves are quite distinct from those on the vegetables. Biological studies conducted at Beltsville, Md., however, showed that the chrysanthemum leaf miners preferred southern peas and tomatoes to chrysanthemums and, furthermore, their mines on the vegetables were similar to those made by the vegetable leaf miners, indicating that the insects may be of the same species. This suspected synonymy of the two leaf miners was further indicated by crossing leaf miners collected from tomato in South Carolina with those from chrysanthemum in Maryland. The progeny of reciprocal crosses of the two colonies reared on southern peas deposited fertile eggs. Multiple matings took place and one cross-mated female laid 154 fertile eggs in 26 days. Other biological studies

at Charleston, S.C., indicated that the damage to tomatoes in that State was due chiefly to progeny of insects introduced on transplants from Florida. In 1962 several species of parasites accompanied the pest insects into South Carolina.

2. Six-Spotted Leafhopper. Further studies, with headquarters at Fort Collins, Colo., on the spring movement of the six-spotted leafhopper, Macrosteles fascifrons, showed that during May the insects move quite rapidly from Texas and Oklahoma northward across the Western Great Plains. In the first week of April a survey showed no leafhoppers north of Oklahoma but by May 12 comparatively large numbers were taken in northern South Dakota. Only adult leafhoppers were taken during May in Kansas, Nebraska, and South Dakota, which indicates a migratory population since the six-spotted leafhopper in this area overwinters in the egg stage. Female leafhoppers move slightly ahead of males. In western South Dakota the proportion of females to males was in the ratio of approximately 2:1, while in southwestern Nebraska and northeastern Colorado males were in greater numbers by about 3:1.

3. Spider Mites. At Beltsville, Md., studies were continued on the biology and mating habits of two species of spider mites, Tetranychus telarius and T. cinnabarinus. Unfertilized females of either species produced only males. A female usually mates only once, whether newly emerged or several days old. In the absence of males of the same species, the females mate readily with males of the opposite species to produce sterile hybrid female offspring. A single male can mate with at least 5 females. When equal numbers of males of each species are moved at the same time to leaves infested with virgin females of a single species, a larger proportion of the females mate with their own species to produce normal female progeny. When 3 to 5 times as many males of the opposite species are present, most of the females produce hybrid progeny. In established colonies each male usually selects a female before she molts to the adult stage and keeps other males away. When an established population of telarius mites was flooded with 4 cinnabarinus males for every telarius male, there was only 11% hybridization. Apparently the strange males could not compete successfully with the males already present for possession of the pre-adult females. In the ensuing combats many males were dislodged from the plants.

4. Drosophila. The cost of rearing Drosophila flies for experimental purposes was reduced more than 95% as a result of research at Beltsville, Md. This will facilitate studies on possible control by utilization of the sterile-male technique. Approximately 300,000 flies are needed weekly for these studies.

Their production by previous methods required 1,200 Ehrlemeyer flasks in continuous operation. Handling, washing, and sterilization became a problem. Available throw-away containers of similar shape and size were unsatisfactory. A method was developed for substituting a 14- by 20-inch wooden greenhouse flat with a disposable lining for each 27 flasks. A flat requires less labor than a single flask. Each flat yields about 75,000 flies from each batch of rearing medium or the equivalent of production from about 27 flasks. The control of moisture is critical for successful rearing of Drosophila. This is accomplished by stretching polyethylene over the cheesecloth covering leaving about 1 inch of exposed cloth across each end. The flies are removed by attracting them to light into a collecting chamber where they are collected rapidly by two people working together with a vacuum tube.

Also, at Beltsville, field studies of Drosophila populations in experimental tomato plantings showed the need for a marker to identify field-released chemosterilant-treated adults. Seven water-soluble fluorescent biological stains sprayed on laboratory-reared Drosophila adults at 1% strength left residues that were readily seen under a binocular microscope for at least two weeks. The best stain tested was rhodamine B. The use of biological stains as markers provides a simple and inexpensive method of identifying field-released insects in population studies. Marked adults were caught 2 miles from the point of release.

B. Insecticidal and Cultural Control

1. Beet Leafhopper on Beans, Tomatoes and Other Vegetables. Continued cooperation was given, in an advisory capacity to the Bureau of Land Management of the U. S. Department of the Interior in the $3 million 10-year program initiated in July 1958 to control the beet leafhopper in southern Idaho bean fields by seeding its desert breeding areas of approximately 300,000 acres with suitable non-host perennial range grasses. It is hoped that the annual cycle of host plants of the beet leafhopper can be broken by the elimination of its most important summer host plant, Russian-thistle, thereby reducing and perhaps eventually eliminating the beet leafhopper-curly top menace. It is too early to hope for any demonstration of success in the program. However, approximately 116,000 acres have been seeded by the Bureau of Land Management primarily with crested wheatgrass under this program, with a total appropriation of $750,000. Many problems have been encountered; there have been some germination failures, severe competition from annual cheatgrass, wind erosion of top soil, and rabbit and insect damage which required reseeding of some acreages. Possible solutions of these problems are under study. Some of the seedings have already

become well established and eventually should pay dividends, not only in insect control but in increased carrying capacity of the range, reduced fire hazard on the range, and as an aid to soil erosion control.

In Utah, phorate and Di-syston continued to give promising results as systemic insecticides applied to the soil for beet leafhopper control on tomato. They are too hazardous to apply as emulsions in the transplant water. It is possible they may be applied with safety as granules in the transplant hole after the transplant water. Residue studies indicate that a residue tolerance will be needed, as very small but measurable quantities of the insecticide sometimes appear in the ripe fruit. Applications of these systemics as granules may need to be supplemented by a foliage spray of a less persistent insecticide such as Phosdrin. Further studies will be needed to develop dosages and schedules of application.

In field plots in Idaho dimethoate applied for control of the insect vector reduced curly top incidence in beans 40 to 47% when used as a foliage spray, either with or without beet juice, and more than doubled the yield. The presence of the beet juice improved the spray in terms of increased yield but did not reduce curly top. The role of beet juice in such sprays is not understood. In laboratory tests phorate-beet juice spray continued to protect bean plants from curly top but dimethoate, Phosdrin, and phosphate 100, each with beet juice, gave similar results. Of 28 materials tested in the laboratory, only 6 appeared to be worthy of further tests, including diazinon, Zectran, American Cyanamid 43,073, and ENT compounds 24,964, 25,755, and 25,784.

2. Pea Aphid on Peas. Granular systemics placed in the seed furrow as peas are planted continued to show promise in pea aphid control. Di-syston at 2 pounds per acre in Washington gave adequate protection against the aphids until about 3 weeks before processing maturity, and in 2 out of 4 seasons the protection was adequate until canning maturity. The insecticide killed small nymphs and also, in some cases, reduced the reproductive capacity of the female aphids. Chemical residue and bioassay tests both showed that the material was more concentrated in the lowest third of the vines at harvesttime, and that residues in the peas and in the upper part of the vines were low (0.07 to 0.40 p.p.m.). Cutting the vines slightly higher than present practice would eliminate most of the chemical from vines to be used for forage.

3. Cowpea Curculio. Endosulfan (Thiodan) spray and dieldrin soil treatment showed promise for cowpea curculio control in field experiments in South Carolina. Endosulfan applied as a spray at 0.75 pound per acre per application gave 86% reduction in the numbers of cowpea curculio larvae that reached maturity in samples of pods from treated plots of the California Blackeye variety of southern peas (edible cowpeas). A single application of 3 pounds of dieldrin applied as granules to the soil surface a few days before blooming began gave 75% control of the larvae. Toxaphene, the currently recommended insecticide, gave 79% and dimethoate gave 58% control when applied as sprays at 2.5 pounds and 1 pound, respectively. Sprays of Sevin (1.5 pounds), diazinon (0.5 pound), and naled (Dibrom) (1 pound) and a soil application of phorate (3 pounds) were of no significant value. All insecticides were applied in 50 gallons of water per acre with tractor-mounted equipment. Four applications were made at intervals of 4 or 5 days during July 1961, beginning when the first blossoms opened.

4. Squash Vine Borer. Sevin and endrin gave excellent control of squash vine borer in field plot studies on Yellow Crookneck summer squash in South Carolina. Sevin at 1 pound per acre and endrin at 0.25 pound reduced the number of borers in the vines by 98 and 99% and allowed only 3 and 4% of the vines, respectively, to be injured by the insect. Three weekly applications were made. Sixty-eight percent of the untreated plants were injured, with an average of 1.6 borers per untreated plant. Endosulfan (0.75 pound per acre) and lindane (0.25 pound per acre) were less effective than Sevin and endrin. Other materials tested were inadequate. This finding is important to squash growers as they have not previously had satisfactory control measures for this insect.

5. Leaf Miners on Tomato, Pepper and Other Vegetables. Dimethoate showed outstanding toxicity to leaf miners in South Carolina laboratory tests. Nineteen of the most promising compounds available were tested. Dimethoate was at least twice as toxic as any of the others to leaf miner larvae of an undescribed species of Liriomyza (near commelinae) which has become resistant to diazinon and has been very destructive to tomatoes and other vegetables in South Carolina and Florida. Next most effective materials were Shell Development 3562, Guthion, Bayer 29493, and Zectran. Other materials that showed considerable toxicity, but only at high dosages, were naled, Methyl Trithion, parathion, and mixtures of toxaphene with parathion or diazinon. Infested cowpea seedlings were dipped in various concentrations of the test compounds. The effectiveness of the treatments was based on the numbers of larvae that emerged from the leaves and pupated.

6. Cabbage Looper on Leafy Vegetables. The most important insect problem on leafy vegetables is the difficulty in avoiding hazardous residues of insecticides in the control of various caterpillars, such as the cabbage looper, an insect that also attacks numerous other crops. Limited experiments in South Carolina, Arizona and California continued to show the superiority of endrin for cabbage looper control, but because of the residue hazard this insecticide cannot be used after the appearance of any foliage that is to be eaten or marketed. In the search for materials that can be used safely, the more promising were Phosdrin, parathion, naled, and two pathogens, Bacillus thuringiensis and the polyhedral virus. Other materials either gave inferior control or their residues were too persistent or too toxic.

7. Banded Cucumber Beetle on Sweetpotato. At Charleston, S.C., several compounds showed promise in laboratory screening tests in control of larvae of banded cucumber beetle of South Carolina and Louisiana strains. Of 28 compounds tested May-July 1961, the most promising were Zinophos, parathion, phorate, diazinon, and Bayer 38156 at the equivalent of 1 to 2 pounds per 6-inch acre and DDT and Perthane at 10 to 20 pounds. Zinophos was especially toxic, killing 100% of the larvae at a dosage of 0.5 pound. Endosulfan and Sevin at 10 pounds, Telodrin at 4 pounds, and Guthion at 2 pounds were less effective but showed sufficient toxicity to justify small-scale field tests. Ethion, Kepone, V-C 13, endrin, dimethoate, dieldrin, Delnav, toxaphene, chlordane. carbophenothion (Trithion), Bacillus thuringiensis, and Zectran showed little promise of practical nature. Aldrin was ineffective at dosages up to 20 pounds per acre and its toxicity was not increased by either of the two anti-resistant compounds, Armour ARD 226 and N,N dibutyl-p-chlorobenzenesulfonamide. Half-grown larvae, reared from adults collected at Charleston, S.C., were caged for 1 week in soil containing the various compounds named above. Larvae reared at Charleston from adults collected at Ormandville, La., by entomologists of the Louisiana Agricultural Experiment Station were approximately as susceptible to several dosages of Zinophos, DDT, parathion, aldrin, diazinon, Telodrin, endosulfan and Sevin as the Charleston strain.

8. Pickleworm on Cucurbits. In studies in South Carolina on melons and other cucurbits, Sevin continued to be the most promising of several new insecticides tested for pickleworm control. Excellent control of this insect for the season was obtained with 1/2 pound of Sevin per acre in each of 6 weekly spray applications on cucumbers, but on squash 1 pound per acre was required. When these dosages were reduced by one-half, the control was not adequate. Sevin was also effective against the

melon aphid on squash and at the 1-pound dosage it was of some value in the control of leaf miners on both crops. Dimethoate at 1 pound per acre controlled the pickleworm adequately on cucumbers but not on squash. Dimethoate gave outstanding control of the melon aphid and the leaf miner. Naled at 1.5 pound gave near-adequate control of the pickleworm on cucumbers and was of some value against the leaf miner. Fruits from naled-treated plots, however, were noticeably lighter in color than those from untreated plots and those receiving other insecticides. Bayer 29493 (0.25 pound per acre) did not give adequate control of either the pickleworm or the leaf miner, but the dosage may have been too low. Bacillus thuringiensis and an antifeeding compound (American Cyanamid 24055) showed little promise against any of the insects.

9. Corn Earworm on Sweet Corn. Of 13 insecticides tested for control of the corn earworm on sweet corn at State College, Miss., none were better than DDT or Sevin. Only a single experimental material, Bayer 44646 (4-dimethylamino-m-tolyl methylcarbamate) was as good. DDT and Sevin sprays were not improved by the addition of raw tung oil.

10. Bean Insects and Mites. Continued studies in Maryland and California confirmed previous findings that systemic insecticides are effective against a number of bean insects when applied to the soil at planting time. During most of the growing season Di-syston at 1 pound per acre controlled the Mexican bean beetle and two-spotted spider mite. Tests by the Human Nutrition Research Division showed no adverse affects on the flavor and quality of Top Crop snap beans from a 2-pound per acre dosage of Di-syston or a 4-pound per acre dosage of phorate. Phorate was less effective than Di-syston. The plants treated with each material made more succulent growth than untreated plants. Each material delayed maturity and increased the yield.

C. Insecticide Residue Determinations

1. Parathion Residues. Studies were initiated to determine the low temperature limitations for safe usage of parathion and to obtain information needed as a basis for more adequate instruction to growers on the safe and effective use of this insecticide. In plots of kale in Maryland, sprayed with parathion in September and December, the loss of insecticide was significantly retarded by the lower temperatures in December. Plots treated with 0.5 pound of parathion per 100 gallons of water per acre in September retained only 0.5 p.p.m. of residue 10 days after treatment, which is well below the tolerance of 1.0 p.p.m. Those sprayed

with the same amount of the insecticide in December had a residue of 10.2 p.p.m. after 10 days and 1.3 after 21 days. In September the parathion gave almost 100% kill of cabbage aphids whereas in December the kill was only 35%. These data demonstrate that the 7-day waiting period required after parathion application before harvest is much too short during cold weather. These and other studies have indicated that if the daily maximum temperatures are not well above 60° F., parathion will not be effective and, furthermore, harvest must be postponed a week or two beyond the waiting period specified on the label to avoid excess residues. It is important not to repeat parathion application under these circumstances. The above temperature is only approximate and considerable research will be needed before a satisfactory solution to this problem can be obtained. Parathion and other phosphate insecticides may dissipate from vegetables by evaporation and owe their effectiveness to the vapors.

2. Heptachlor Residues. Analyses were made at Tifton, Ga., of 16 different kinds of vegetables grown in soils that had been treated by the Plant Pest Control Division with heptachlor granules at rates of 1/4 to 1/2 pound of heptachlor per acre. Only onions and radishes showed detectable residues, ranging from 0.03 to 0.08 p.p.m. of heptachlor epoxide in onions and from 0.13 to 0.20 p.p.m. in radishes.

3. Chlordane Residues. Chlordane residues in excess of the tolerance of 0.3 p.p.m. were found in carrots grown in South Carolina in soil treated with as little as 2 pounds of chlordane per acre. It had been known that the 10-pound dosage would leave excess residues but there was hope that dosages of 2 or possibly 5 pounds per acre would be satisfactory. In view of these studies recommendations of chlordane for the control of wireworms and the carrot rust fly on carrots were discontinued.

4. Phosdrin Residues. Phosdrin residues persist on glass and filter paper. Phosdrin residue from aerosol applications on filter paper and pyrex petri dishes has a prolonged aphicidal toxicity as shown by tests at Beltsville, Md. An aerosol applied at 1 gram of Phosdrin per 1,000 cubic feet destroyed all green peach aphids, non-resistant two-spotted spider mites, and citrus mealybugs. To study the prolonged effect of Phosdrin residues, 6-inch pyrex petri dishes with and without filter papers in the bottom were left open in the greenhouse during the exposure period then closed and placed on a laboratory table. Aphids on leaves placed in the dishes at intervals up to 8 months after treatment were killed in each dish containing a treated filter paper but not in untreated dishes either with or without untreated filter paper. The treated filter papers in treated dishes gave 72 to 80% kill 16 months after treatment whereas the treated filter papers in untreated dishes killed only 35%.

5. Lindane Residues. In cooperative studies at Beltsville, Md., with the Human Nutrition Research Division and the Ohio Agricultural Experiment Station, the flavor of tomatoes grown in greenhouse soils treated with 4 pounds of lindane per acre was not adversely affected. A 25% lindane wettable powder was applied to the soil surface in a commercial tomato greenhouse and worked into the soil for the control of the garden symphylan. Chemical analysis of the harvested tomatoes showed no lindane residues. Similar results were obtained with lindane similarly applied at 8 pounds per acre or used as a drench around the transplants at 1 and 2 pounds per acre.

6. Other Residues. At Beltsville, Md., Tifton, Ga., and Yakima, Wash., numerous samples of livestock feed from experimental plantings of beans, peas, and sweet corn treated with insecticides were analyzed for residues as an essential part of the effort to develop methods of controlling insects on these crops without contaminating livestock feed with residues of chlorinated hydrocarbons and other insecticides. Likewise, numerous samples of marketable vegetables of various kinds were analyzed for residues as a part of the effort to develop safer methods of insect control on the crops. The samples came from various Federal and State stations from all parts of the country. For example, samples from 27 different vegetable crops were furnished by the Federal station at Riverside, Calif.

D. Biological Control

1. Spider Mites. In Maryland basic studies were initiated on the utilization of predators in the control of spider mites. In laboratory tests two predaceous mites, Phytoseiulus persimilis and Typhlodromus sp., displayed high tolerances to residues of a large number of insecticides, acaricides, and fungicides and a variable susceptibility to others. Phytoseiulus mites were introduced into one commercial greenhouse where they appeared to become established and to keep the spider mites under control until they were killed by mistake by the unnecessary application of insecticides. Preliminary studies indicated that these predaceous mites can be stockpiled for later release. Adults and eggs of the predators tolerated storage at temperatures as low as 40° F. for at least two weeks, then resumed normal activity when returned to greenhouse temperatures. Adults also resumed activity after two weeks storage at 35° F. At 50° F. eggs hatched and adults continued to feed on available spider mites.

2. Pea Aphid. Two parasites of the pea aphid that were native to New Jersey, Aphidus pisivorus and Praon simulans, were introduced into southeastern Washington and survived at least two winters in that State. However, their effectiveness was greatly reduced by the scarcity of aphids during winter and late summer. This finding indicated it might be profitable to supplement the population of parasites in early spring and early fall by releases from reared greenhouse stocks. Therefore, 2,500 A. pisivorus adults were reared in the winter of 1961-62 and released in late February and early March in alfalfa fields in Washington where the aphids overwinter. The released adults spread over the area so rapidly it was difficult to check their efficiency. However, there was a high parasitism over the entire area of intense alfalfa production for about 2 or 3 miles leeward of the release point. Indications were that releases early in the spring would be more effective than releases early in the fall. It was of significance that pisivorus parasites reared from pea aphids on alfalfa would not attack pea aphids feeding on peas. This specificity is a serious disadvantage.

3. Cabbage Looper. Of a number of commercial Bacillus thuringiensis dusts and sprays tested against the cabbage looper in South Carolina, three gave as good control as naled, which is one of the most effective insecticides that can be used on leafy vegetables close to harvest. The Bacillus preparations were Bakthane L-69 (75 billion spores per gram) at 8 pounds per acre, Bakthane dust (15 billion spores per gram) and Biotrol dust (5 billion spores per gram). The dusts were applied at 20 pounds per acre. The naled as a check was used in a spray at 2 pounds per acre. All were applied in 4 weekly applications during May 1961. Naled gave 64% control of the looper population and allowed only 6.9% of the cabbage plants to be damaged. Treatments that were less effective included Biotrol (25 billion spores per gram) and Thuricide (30 billion spores per gram) at 8 pounds per acre in sprays and Thuricide at 4 pounds per acre in a dust.

The addition of corn oil to one commercial preparation of Bacillus thuringiensis increased its effectiveness against the cabbage looper on cabbage in field tests but did not increase the effectiveness of preparations of the Bacillus sold by two other manufacturers. The first preparation was the most effective even without the oil.

4. Tomato and Bean Insects. In field experiments in California in comparison with insecticides, Bacillus thuringiensis dust gave very promising results against the tomato fruitworm and tomato hornworm. Three applications were made of a dust containing 5 billion spores per gram. The dust did not control leaf miners and cutworms on the tomatoes. In similar experiments on beans, the Bacillus did not control the lima bean pod borer.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Drosophila. Preliminary tests were made at Beltsville, Md., on the effect of gamma radiation on the fertility of Drosophila melanogaster. Untreated females mated with males exposed to gamma radiation at 5 kr in the larval state, 10-20 kr in the pupal stage or 20 kr in the adult stage deposited the normal number of eggs but none of them hatched. At the same dosages females irradiated in the pupal or adult stage and mated with untreated males produced few or no eggs and females irradiated in the larval stage produced fertile eggs but in smaller numbers. The longevity of males or females irradiated in the pupal or adult stage was not affected while the longevity of those irradiated in the larval stage was reduced. In multiple mating tests untreated female flies mated with irradiated males produced sterile eggs until a subsequent mating with untreated males after which they produced viable eggs that developed into adults. Untreated female flies mated with normal males produced viable eggs and continued to do so after a subsequent mating with irradiated males. This effect of multiple mating needs further study before any conclusion can be drawn. In limited tests sterile and normal males in the ratio of 5:1 gave 55 to 60% reductions of the progeny of normal females with which they mated. The 20 kr dosage of gamma radiation was effective on adult males 1, 5, and 10 days after emergence. One treated male mated with 5 different untreated females in an 8-hour period caused each to produce sterile eggs. This male repeated this performance after 5 days and again after 10 days.

Also at Beltsville, progress in the development of techniques for sterilizing Drosophila by chemicals has paralleled that with gamma radiation. Effective dosages of apholate have been developed and exploratory tests initiated on control of Drosophila in small isolated fields of tomatoes by sustained releases of sterile males.

2. Spider Mites. At Beltsville, Md., apholate residues persisted on lima bean foliage in preliminary greenhouse tests for at least 3 days and sterilized the progeny of exposed spider mite adults and young. Uninfested bean foliage was dipped in 0.5% apholate solution. The foliage was allowed to dry before female mites were permitted to feed on it. Most progeny of the females that fed for 24 hours during the first two days after treatment died either as eggs or as newly hatched larvae; some of the few that survived were sterilized. A high proportion of the progeny of females that fed in the presence of 3- to 6-day-old residues reached maturity but the majority of the females were sterile. Similar but less pronounced results were obtained when larvae, protonymphs and deutonymphs were placed on the treated foliage.

3. Mexican Bean Beetle. In preliminary tests sterility techniques showed promise for the Mexican bean beetle. At Beltsville, both gamma radiation and the alkylating agent, apholate, were effective in sterilizing adult males and females of the Mexican bean beetle. Sterilization was produced with ionizing radiation when the adults were exposed to 10 or 20 kr. Complete sterilization of female pupae was obtained at doses of 1, 5, 10, or 20 kr. Male pupae were sterilized at doses of 5, 10, or 20 kr. Larvae were more susceptible to direct radiation effects than pupae, and pupae more susceptible than adults. Adult male or female bean beetles dipped in 0.5% apholate or confined for 48 hours on bean foliage treated with the same formulations were completely sterilized. Untreated females mated with treated males (irradiated or apholate) deposited the normal number of eggs, none of which hatched. Treated females (irradiated or apholate) mated with untreated males deposited very few or no eggs. Adult beetles of either sex irradiated in the pupal or adult stage or treated with apholate were shorter lived than normal. Untreated female beetles mated first with irradiated or apholate treated males produced sterile eggs; subsequent matings with untreated males resulted in the production of viable eggs.

4. Other Vegetable Insects. Exploratory studies on the natural sex lures of insects were conducted on the cabbage looper at Riverside, Calif.; the southern potato wireworm at Charleston, S.C.; the six-spotted leafhopper and Colorado potato beetle at Fort Collins, Colo.; the beet leafhopper, sugar beet webworm and onion maggot at Twin Falls, Idaho; and the zebra caterpillar and bertha armyworm at Walla Walla, Wash. There is little indication of chemical lures in the leafhoppers, the onion maggot, and the Colorado potato beetle but they appear to be present in the other insects, although the first exploratory attempts to make attractive crude extracts have not been successful. Considerable progress has been made in accumulating necessary basic information on the various insects. A serious bottleneck in the work on wireworm has been the inability to separate the sexes in any stage without damage to the insects. Recently, however, a method has been discovered for sexing the pupae.

F. Evaluation of Equipment for Insect Detection and Control

1. Application of Insecticides with Ground Equipment. Basic studies on the coverage of foliage with insecticides from ground equipment were continued at Forest Grove, Oreg., in cooperation with the agricultural engineers. Laboratory or shop tests showed that the usual method of locating and adjusting nozzles by eye so that the spray cloud looks right falls far short of producing

maximum foliage penetration and coverage when the machine is in motion. There is a wide variation in the amount of spray deposited on the upper and lower leaf surfaces at various positions, forward, aft, right or left, at various heights on the plant. Much of the deposit variation was due to nozzle type, location, and orientation and to the shielding effect of the foliage. Penetration and uniformity were improved when a supplemental air blast was used. Progress is being made in the establishment of basic zones of deposit for various nozzle positions.

Experiments at Charleston, S. C., showed 5 spray nozzles per row to be needed to efficiently apply insecticide sprays to cabbage for the control of the cabbage looper. One nozzle was directed downward over the center of the row. One drop nozzle was used on each side of the row to direct the spray downward at an angle of about 45° towards the plants and another drop nozzle was used on each side to direct the spray upward toward the plants at about the same angle. The upper pair of drop nozzles was located a few inches above the level of tops of plants and the lower pair about one-third the distance from ground to top of plants. This arrangement kept 90% of plants free of caterpillar injury as compared with 71% when 3 regular nozzles were used. Intermediate results were obtained when 1 nozzle was used with 2 drops. These differences in the performance of the nozzle arrangements were about the same when 100 gallons of spray were applied per acre as when only 20 gallons were applied, and there were no appreciable differences in the effectiveness of the two volumes of spray in control of the loopers. In all tests there were two applications of toxaphene, at 2 pounds per acre, before cabbage plants began heading, followed with two applications of naled at the same dosage.

2. Application of Insecticides with Aircraft. Previous studies at Forest Grove, Oreg., of spray distribution patterns from biplanes showed a characteristic low deposit right of center and a high deposit left of center. This irregularity in rate across the swath can be improved somewhat with the use of an asymmetrical nozzle arrangement. Similar studies were made with the Rawdon low-wing monoplane using symmetrical and asymmetrical nozzle arrangements and hydraulic motor-driven and fan-driven spray pumps with the following results: (1) changing nozzles to a non-symmetrical arrangement does not appear to improve the uniformity of pattern of the Rawdon low-wing monoplane; (2) a wind-driven spray pump mounted externally does not appear to affect the pattern laid down by the Rawdon; (3) correlation analysis shows a substantial similarity of relationship between the patterns laid down by the Rawdon low-wing monoplane and the Piper Cub high-wing monoplane; and (4) the characteristic flight pattern of monoplanes studied is different from that of biplanes.

Progress was made at the Forest Grove station on the development of a streamlined wing lateral distributor for moving and dispensing granular materials from a central hopper outward under the wings to give optimum swath width. Studies of patterns obtained from material released at various points from a small moveable hopper and from a test model of a distributor on both the Rawdon and Cessna 182 indicated approximate locations of release points needed for the desired swath patterns. Further pattern studies explored the possibility of widening the swath by means of fins, spoilers, scoops and other means of carrying the material farther outboard in the resulting air currents. The studies indicated that for optimum swath width and minimum drag, a lateral conveyor would be needed to carry at least a portion of the material outboard as far as 9 to 13 feet either side of center. This should produce a 40-50 foot swath. Such a conveyor is now in the course of construction to be tested as a streamlined, low-drag distributor beneath the wings.

As a continuation of work started in Oregon in 1959 on analysis of foliage agitation by means of movies made during airplane flights over the plants, measurements were made and plotted of a series of flights of the Rawdon flown with flaps down and flaps up over sweet corn. Analysis of charts of movement from these flights shows a very decided effect on the air turbulence within the plant canopy, especially in the central 24-foot portion of the swath. Whereas maximum vertical movement of leaves in the "flaps up" flights was 1.2 inches and marked agitation lasted less than 1 second, the maximum vertical movement with flaps down was 3.6 inches and occurred nearly 3.4 seconds after passage of the airplane. Movement was greatest 12 feet left of center. Maximum lateral movement of the leaves in the "flaps up" flights was 3 inches at the 12-foot left position and 0.75 second after passage. With flaps down the maximum lateral movement was 11.8 inches at the station 6 feet right of center and 0.75 second after passage of the airplane. However, as for the vertical movement, the violent lateral movement continued for about 4 seconds. These studies indicate that the use of "flaps down" on an airplane should aid materially in securing more uniform coverage of spray within a plant canopy by reason of greater foliage agitation over the period of time that most of the spray is being deposited.

In Oregon tests of a PA 25, Pawnee agricultural airplane, a low-winged monoplane powered with a 150 hp. Lycoming engine and equipped with a distributor for granular insecticides, gave a reasonably uniform deposit of granular insecticide over an effective 30-foot swath from 3- to 8-foot flight elevation. The uniformity of deposit was improved by adjusting the louvers in the throat of

the distributor to deliver more insecticide in the center portion of the swath than had been obtained with the factory setting. This adjustment largely eliminated the characteristic low deposit in the center of the swath caused by the disturbing effect of the propeller. Similar deposit patterns were obtained from flights at a 25-foot elevation except that the effective swath width was broadened to 40 feet.

In Oregon the Cessna 182 high-wing monoplane was equipped with a 70-gallon Sorensen fiberglass belly tank and a geared spray pump, driven by a Simplex 6-blade delrin plastic fan, and experimental spray booms at various locations and of different lengths. Flight air speed was 110 m.p.h. and most tests were flown at approximately 5 to 6 feet above the ground. Forty-four spray pattern tests were conducted at the Hillsboro, Oregon, Airport, with a water spray containing a red tracer dye. The usual laboratory procedures were followed using a photoelectric colorimeter to determine the spray deposit patterns. The objectives were to determine (a) the basic forms of spray distribution patterns produced by empirical symmetrical arrangements of 22 spray nozzles on a 20-foot 4-inch boom and 31 nozzles on a 25-foot 4-inch boom; (b) the relationship of the length of the boom to the development of spray-laden wingtip curls and the swath widths of the resulting spray patterns; and (c) the effect of the distance of the outboard end of the boom from the wing on the spray deposit pattern. On the basis of the above tests the 31-foot 8-inch boom with straight sections extending to 15 feet 10 inches either side of center, raised at the outer ends to 40 inches beneath the wing and equipped with a symmetrical, but unevenly spaced, nozzle arrangement was selected for field insecticide tests with this Cessna 182 airplane. This equipment, with the airplane flown at a 40-foot spacing and an elevation of 5 to 6 feet gave satisfactorily uniform coverage across the swaths at an average mean rate of 5 gallons per acre in experimental plot applications.

G. Varietal Evaluation for Insect Control

1. Corn Earworm on Sweet Corn. Studies on sweet corn resistance to the corn earworm were continued at Tifton, Ga., and West Lafayette, Ind., with efforts being made to utilize the lethal silk factor. At Tifton, most inbreds tested showed less earworm resistance than in previous years under lighter infestation at West Lafayette. However, several inbreds continued to show considerable resistance. Hybrids with the inbred 366 showed more resistance than others and had fair quality. All corn introductions were rated as highly susceptible except Zapalote Chico, a flint corn from Mexico, which had the highest resistance of any inbred. This variety is poorly

adapted to Tifton but several crosses were made with inbreds having sufficient vigor so that future selecting and selfing can be done. Five selfed inbreds with Z. Chico in the line for three generations showed considerable earworm resistance.

All crosses evaluated at West Lafayette were more resistant to earworm than the check, Aristogold Bantam, with several lines approaching immunity. Some of the highly resistant crosses were of commercial quality while a few others, not quite so resistant, were outstanding in ear type. Corn earworm larvae penetrated deeper into the ears of a resistant single cross sweet corn than into those of a susceptible single cross. Fewer larvae fed on the silk of the resistant cross and fewer reached maturity.

H. Insect Vectors of Diseases

1. Vectors of Mosaic Diseases of Cantaloup. At Mesa, Ariz., seven aphids were incriminated as vectors of mosaic diseases of cantaloup, which seriously affect the crop in the Southwest. Greenhouse tests made in cooperation with the Arizona Agricultural Experiment Station pathologists indicated that the green peach aphid is the most efficient of several vectors of the two severe mosaic diseases of cantaloup in the Southwest. Aphids of this species carrying watermelon mosaic virus infected 95% of the cantaloup plants fed upon while those carrying cucumber mosaic virus infected 83%. The next most efficient vector infected only 30 and 39% of the cantaloup plants with the two viruses, respectively. The other vectors in order of vector efficiency were the rusty plum aphid, the corn leaf aphid, the cabbage aphid, the lettuce stem aphid (Macrosiphum barri) and the pea aphid. Each of these aphids except the cabbage aphid transmitted both viruses. The cabbage aphid only transmitted the cucumber mosaic virus and may prove useful in separating the two viruses in experimental work. In these tests the aphids were starved for one hour before being given an acquisition feeding period of one hour on excised runner tips of diseased cantaloup plants, after which a 24-hour transmission feeding period was allowed. Twenty young cantaloup plants grown under insect-free conditions in the greenhouse were used in each test and 10 aphids were placed on each plant. Negative results were obtained with a leaf miner fly, Liriomyza sp.; three leafhoppers, Circulifer tenellus, Acinopterus productus and Empoasca sp.; and a spider mite.

Aphids migrating to lettuce and sugar beets in November and December were tested as possible carriers of these viruses. One lot of migrant aphids infected 20% of the test plants with cucumber mosaic virus. This indicates that in the fall the green peach aphid

transmits this virus to susceptible host plants which serve as virus reservoirs for later aphid migrations to the cantaloups the following spring. In these tests 20 young cantaloup plants were caged in the greenhouse prior to their transfer to the field. Ten winged aphids were introduced directly into each cage and allowed to feed for 24 hours. The aphids were then killed with an insecticide and the plants retained for observation.

PUBLICATIONS REPORT RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Cook, W. C. 1961. Relation of environment to photosensitivity of insects. (Summary) Part of Symposium on Response of Insects to Induced Light, ARS-20-10:36-38.

Cuthbert, Frank P., Jr. 1962. A method of rearing southern potato wireworm. Jour. Econ. Ent. 55(2):262-263.

Henneberry, T. J. 1962. The effect of plant nutrition on the fecundity of two strains of the two-spotted spider mite. Jour. Econ. Ent. 55(1):134-137.

Lieberman, F. V., Dicke, F. F., and Hills, Orin A. 1961. Some insect pests of important seed crops. "Seeds" The Yearbook of Agriculture for 1961:251-258.

Wave, H. E. 1962. Seasonal distribution of Drosophilid flies in Beltsville, Maryland, tomato fields. Jour. Econ. Ent. 55(3):409-411.

Insecticidal and Cultural Control

Agric. Res. Serv. and Fed. Ext. Serv. 1962. Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock for 1962. USDA Agriculture Handbook No. 120. (Revised)

Cuthbert, F. P., Jr., and Reid, W. J., Jr. 1961. Screening tests of additional compounds for toxicity to the southern potato wireworm. ARS-33-69.

Cuthbert, F. P., Jr., and Reid, W. J., Jr. 1962. Laboratory tests for toxicity to larvae of the banded cucumber beetle. USDA ARS-33-72.

Elmore, J. C., and Magor, Richard. 1962. Insecticide experiments to control green peach aphid and pepper weevil on peppers. Jour. Econ. Ent. 55(3):375-377.

Getzendaner, C. W. 1960. The European earwig--how to control it. USDA Home and Garden Bulletin No. 75.

Harries, F. H. 1961. Effects of mixtures of cube with various drugs on the Mexican bean beetle. Jour. Econ. Ent. 54(3):599-600.

Harries, F. H. 1961. Laboratory tests of insecticides against the salt-marsh caterpillar. Jour. Econ. Ent. 54(6):1266.

Harries, F. H., and Valcarce, A. C. 1962. Insecticide tests on the corn earworm as a pest of lettuce in Arizona. Jour. Econ. Ent. 55(1):112-115.

Henneberry, T. J., Taylor, E. A., and Boswell, A. L. 1961. The effect of Tedion on the eggs and larvae of three strains of the two-spotted spider mite. Jour. Econ. Ent. 54(1):168-169.

Reed, L. B., Bushland, R. C., and Eddy, G. W. 1962. Systemic insecticides. Yearbook of Agriculture 1962, p. 340-343.
Shands, W. A., and Simpson, G. W. 1961. Aphid control reduces leafroll spread. Potato Councillor, p. 13-14.
Shands, W. A., and Simpson, G. W. 1961. Insecticide applications affect leafroll spread. Maine Farm Res. 9(1):3-7.
Smith, F. F. 1961. Use and limitations of Selenium as an insecticide. USDA Agriculture Handbook No. 200, Selenium in Agriculture.
Wester, R. E., and Smith, Floyd F. 1962. Systemic insecticides for Mexican bean beetle control. Agric. Chem. 17(4):44-46.

Insecticide Residue Determinations

Clore, W. J., Westlake, W. E., Walker, Kenneth C., and Boswell, Victor R. 1961. Residual effect of soil insecticides on crop plants. Wash. Agric. Expt. Stations Bull. 627, 9 p.
Dawsey, L. H., Woodham, D. W., and Lofgren, C. S. 1961. Heptachlor and heptachlor epoxide residues on truck crops. Jour. Econ. Ent. 54(6):1264-5.
Walker, Kenneth C., and Westlake, W. E. 1960. A history of residue tolerances and how they are established. Wash. State Hort. Assoc. Proc. 56:221-225.
Westlake, W. E., and San Antonio, J. P. 1960. Insecticide residues in plants, animals, and soils. Proc. of Symposium held April 27-29, 1960, on "The Nature and Fate of Chemicals Applied to Soils, Plants, and Animals," ARS 20-9, p. 105-115.

Biological Control

Elmore, J. C. 1961. Control of the cabbage looper with a nuclear polyhedrosis virus disease. Jour. Econ. Ent. 54(1): 47-50.

Insect Sterility, Attractants and Other New Approaches to Control

Shands, W. A., and Simpson, G. W. 1961. New approaches to aphid and virus disease control in potato fields. Maine Farm Res. 8(4):18-20.

Evaluation of Equipment for Insect Detection and Control

Getzendaner, C. W., and Young, V. D. 1960. Recent developments in spray equipment. Oregon State Hort Soc. Ann. Rept. 52:124.
Schopp, Ralph, and Landis, B. J. 1961. A portable sprayer for experimental plots. Jour. Econ. Ent. 54(3):604-605.

Wester, R. E., and Smith, Floyd F. 1961. Safe application of granular organic phosphate insecticides. Agric. Chem. 16(1): 59, 75.

Young, V. D., and Getzendaner, C. W. 1960. Improved equipment for the application of pesticides to row crops. Oregon State Hort. Soc. Ann. Rept. 52:123.

Young, V. D., Winterfield, R. G., Deonier, C. E., and Getzendaner, C. W. 1961. Factors influencing the deposit position of granular materials applied by aircraft at low flight levels with fixed-wing aircraft. Paper No. 61-414. Amer. Soc. Agric. Engr., Chicago, Ill.

Varietal Evaluation for Insect Resistance

Walter, E. V. 1962. Corn earworm resistance in sweet corn inbreds released by several State Experiment Stations. USDA 33-70.

Insect Vectors of Disease

Brierley, Philip, and Smith, Floyd F. 1962. Three cowpea mosaic viruses from gladiolus. The Plant Disease Reporter 46(5):335-7.

Hildebrand, E. M., and Smith, F. F. 1961. Comparison of aphid and manual methods for transmitting internal cork and associated viruses of the sweetpotato. Phytopathology 51(7):419-423.

Hills, Orin A., Coudriet, D. L., and Brubaker, R. W. 1960. Investigations of insects and insectborne diseases affecting cantaloups. Cantaloup Res. in Arizona, Rept. No. 195, Agric. Expt. Sta., Univ. of Arizona, p. 27-32.

Hills, O. A., Coudriet, D. L., Brubaker, Ross W., and Kenner, Paul D. 1961. Effect of curly top and cucumber mosaic viruses on cantaloups. Jour. Econ. Ent. 54(5):970-972.

Hills, O. A., Gibson, Kenneth E., and Rochow, W. F. 1961. Insects, viruses, and seed crops. "Seeds" The Yearbook of Agriculture for 1961, p. 258-264.

Smith, F. F. 1961. Insect vectors of cucumber mosaic in gladiolus. GladioGrams No. 48:10-13.

Smith, Floyd F., and Brierley, Philip. 1961. Ornamental plants as virus reservoirs. Jour. Econ. Ent. 54(3):506-508.

AREA 2. POTATO INSECTS

Problem. The profitable production of high-quality potatoes demanded by the consumer necessitates the control of injurious insects. Available control methods involve the use of insecticides, some of which are not adequately effective because of resistance of the insects to them. Certain insecticides may leave undesirable residues on or in potatoes. There is, therefore, continuing need for research to develop safe, effective, and economical procedures for combating potato insects. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is also need for research on the biological control of potato insects and on the evaluation of potato varieties for insect resistance.

USDA PROGRAM

A continuing program involving basic studies on the biology, ecology and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control, is conducted by the Department at Yakima, Wash.; Orono, Maine; Beltsville, Md.; and Charleston, S.C., in cooperation with the respective State Experiment Stations, the Washington Department of Agriculture, the Washington State Potato Commission and industry. Some of the work herein reported was conducted at Fort Collins, Colo. This station was closed in January 1962 and the research underway at that location consolidated with similar investigations at Yakima, Wash.

The Federal scientific effort devoted to research in this area totaled 7.5 professional man-years. Of this number 2.2 was devoted to basic biology; 2.3 to insecticidal and cultural control; 1.7 to insecticide residue determinations; 0.3 to biological control; 0.2 to insect attractants; 0.1 to varietal evaluation for insect resistance; 0.4 to insect vectors of diseases; and 0.3 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 5.6 professional man-years. Of this number 1.2 was devoted to basic biology, physiology and nutrition; 2.9 to insecticidal and cultural control; 0.3 to insecticide residues; 0.2 to varietal evaluation for insect resistance; and 1.0 to insect vectors of diseases. This work is done in 10 States, including New York, Idaho, Oregon, and Connecticut.

Industry. In addition to substantial contributions by industry on synthesis, analysis, formulation, and primary screening of insecticides for general use, which are discussed in another area, several chemical companies conduct some field tests of insecticides against insects and mites that attack potatoes. Some of these companies cooperate with growers. Others have their own experimental acreage. The results of such work are often kept confidential. Exclusive of industry's contributions through grants to and cooperative agreements with State and Federal stations, estimated annual expenditures are equivalent to approximately 4 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology

1. Aphids. After many years of study at Yakima, Wash., it has become apparent that the abundance of overwintering eggs of aphids on woody plants in the Northwest has far less bearing on aphid damage to potatoes than do the weather conditions during spring and summer. During 1961, after a mild winter conducive to aphid survival, unprecedented hot weather during June, July, and August made it impossible for damaging infestations of aphids to develop in potato fields in eastern Washington. During the mild winter of 1960-61, the potato aphid, Macrosiphum euphorbiae, the foxglove aphid, Myzus solani, and the green peach aphid M. persicae, overwintered successfully as summer non-egg-laying forms in central and southeastern Washington. Overwintering hosts of the potato-infesting aphids included alfilaria, Erodium circutarium, a chickweed, Cerastictum sp., clasping-leaved peppergrass, Lepidium perfoliatum, flixweed, Sisymbrium amplexicaule, henbit, Lamium amplexicaule, and shepherd's-purse, Capsella bursa-pastoris. Winged spring migrants were produced on various overwintering weeds sometime prior to the appearance of potato plants in planted fields.

Aphid damage to potato plants had no important effect on the specific gravity of the tubers according to a 5-year study concluded at Orono, Maine. The tendency of the damage to reduce starch content was of no commercial significance. The work was done on Green Mountain and Katahdin varieties and results were published.

In Maine the increased use of sprout inhibitors created conditions favorable for winter survival of aphids when delayed sprouts were allowed to grow on culls discarded from summer storages. Tubers from plantings treated with sprout inhibitors before harvest, when discarded almost a year later, produce short, stubby, succulent sprouts that persist until cold weather. The foxglove aphid and the green peach aphid breed on such sprouts in abandoned cull piles and survive the winter. In contrast, culls from untreated tubers produce early season growth that either matures early or is destroyed by growers to eliminate field sources of diseases. The sparse growth on cull piles produced by discards from summer storages will also need to be destroyed to protect the potato crop from aphids.

2. Leafhoppers. Further studies on the spring movement of the six-spotted leafhopper, Macrosteles fascifrons, directed from the Fort Collins, Colo., station, showed that during May the insects moved rapidly from Texas and Oklahoma northward across the Western Great Plains. In the first week of April a survey showed no leafhoppers north of Oklahoma but by May 12 comparatively large numbers were taken in northern South Dakota. Only adult leafhoppers were collected during May in Kansas, Nebraska and South Dakota. This indicates a migratory population since the six-spotted leafhopper in this area overwinters in the egg stage. Female leafhoppers move slightly ahead of males. In western South Dakota the proportion of females to males was in the ratio of approximately 2:1, while in southwestern Nebraska and northeastern Colorado, males were present in greater numbers by about 3:1.

3. Wireworms. At Charleston, S.C., further studies on the southern potato wireworm confirm earlier indications that this insect has two generations per year and a partial third whereas other wireworms usually require from 1 to 5 years for each generation. The general biology and habits of this new pest have been determined and the information is being prepared for publication as a USDA technical bulletin. A few years ago the southern potato wireworm appeared to be a pest of potato only, and thus received its common name. Now the insect is recognized as a pest of potato, sweetpotato, carrots, beets, tobacco, and strawberry. During 1962 it was recorded for the first time damaging fields of corn. Since fairly satisfactory methods have been developed for control of this wireworm on potato, the work at Charleston is being diverted in part to a study of the insect as a pest of some of the other crops now being infested.

B. Insecticidal and Cultural Control

1. Aphids. Systemic insecticides were partially effective in reducing the spread of leaf roll at Presque Isle, Maine, in studies by the Orono station. Light applications of either of three systemic insecticides in the planting furrow controlled the aphid vectors of leaf roll so that little spread of the disease occurred. In Green Mountain potatoes--a variety rather susceptible to the disease--Di-systongranules at 0.8 pound of active ingredient per acre held the spread of leaf roll to 0.3% in treated plots as compared with 1.9% in untreated plots. Similar results were obtained with demeton at 1 and 1-3/4 pounds per acre. Phorate was somewhat less effective. In the experiments 4% of the plants were grown from leaf-roll infected tubers in order to provide a severe test of the protective value of the aphicidal treatments. The furrow-applied systemic insecticides gave near-perfect control of the aphids until the end of July, after which small numbers developed.

Also, in later experiments on Russet Burbank potatoes in Maine, Di-syston and demeton were each more effective than phorate or Menazon in controlling aphids. The materials were applied in the bottom of the planting furrow at 1 pound per acre for Di-syston and demeton, 1-3/4 pounds for phorate, and 2 pounds for Menazon. The treated plants were almost free of aphids during the early part of summer but small numbers developed in August.

At Yakima, Wash., endrin or parathion were superior to either demeton or endosulfan (Thiodan) in preventing development of net necrosis in potatoes treated for control of leaf roll vectors. In a field of Russet Burbank potatoes containing approximately 3% of chronic or tuber-borne leaf roll, 4 applications of endrin, endosulfan or demeton gave significantly better control of wingless green peach aphids than parathion when each was applied at 1 pound of active ingredient per acre per application. However, after overwintering, the tubers from the endrin and parathion treatments contained much less net necrosis than did tubers from either the endosulfan or demeton plots.

2. Wireworms. Field experiments in South Carolina confirmed previous indications that the southern potato wireworm, Conoderus falli, can be controlled in potato land by insecticides applied to the foliage of fall cover crops to kill adults of the wireworm as they collect for oviposition. Three applications of either parathion or diazinon at 1/2 pound per acre to soybean foliage in August or September reduced the adult population of the wireworm 89 to 99%.

Soil samples screened for the wireworm larvae a month after the last foliage application showed 92% control. This generation of larvae is the one chiefly responsible for damage to potatoes. Fall treatments may not be effective in protecting other crops such as sweetpotatoes.

C. Insecticide Residue Determinations

1. Phorate Residues. Residue studies in Maryland showed that a tolerance is needed to cover the registered use of phorate in potato soil applied at 3 pounds per acre to the furrow or in bands on each side of row at time of planting. Residues of phorate found in washed tubers harvested 77 days after treatment in 8 field plots ranged from 0.3 to 0.9 p.p.m. The phorate content of the potato foliage at this time was slightly higher than that of the tubers. No phorate was found in the tubers or foliage from the 4 check plots. These data substantiate results of preliminary studies in Washington in 1959. Samples from potatoes grown in different soils in Washington and Maine, however, in plots treated with phorate in 1960 and 1961 showed no appreciable residues of phorate in the mature tubers. Until an appropriate residue tolerance is established this outstanding phorate treatment cannot be recommended. No explanation has been found as to why phorate treatment occasionally leaves residues in the harvested tubers.

D. Biological Control

1. Aphids on Potatoes. The Orono, Maine, station obtained partial control of aphids on potatoes in experimental plots at Presque Isle by planting strips of untreated oats between the plots. Ladybird beetles gathered in the oats to feed on the English grain aphid and then moved to the potato plants to feed on the several species of potato-infesting aphids. The most important predators were the 5-spotted and 13-spotted ladybird beetles followed in abundance by syrphid flies and lacewing flies. A survey of parasites of potato aphids, continued for the third year, has shown that of 13 species present, Aphidius nigripes, and Praon sp. are the most important. A survey of fungus diseases of aphids showed the most common to be Entomophthora ignobilis, not previously known to occur in northeastern Maine or to be important as a pathogen on aphids.

E. Insect Attractants

1. Natural Sex Lures. Exploratory studies on the natural sex lures of insects were initiated on the southern potato wireworm at Charleston, S.C., and the six-spotted leafhopper and Colorado potato beetle at Fort Collins, Colo. There was little indication of sex lures in the leafhopper and the Colorado potato beetle but they

appeared to be present in the wireworm. Considerable progress has been made in accumulating necessary basic information on the various insects. A serious bottleneck in the work on wireworms has been the inability to separate the sexes in any stage without damage to the insects. A possible method of sexing the pupae was recently discovered and is now undergoing tests.

G. Insect Vectors of Diseases

1. Aphids and Leafhoppers. Studies at Yakima, Wash., on the six-spotted leafhopper as a vector of purple-top of potatoes (aster yellows of vegetables) indicated that marestail, Erigeron eanadensis, may be important as an overwintering host of the virus. Marestail is a common weed and in 1961 was the most frequently infected of a number of host plants of the disease. In greenhouse tests the virus was transferred from marestail to marestail by the six-spotted leafhopper. However, attempts to transfer the virus from potato to potato or to carrot, aster, endive, or Ladino clover with this insect were unsuccessful. The virus of purple-top is suspected to be one of the causes of net necrosis in potato. If this is true, both aphids and leafhoppers are indirectly responsible for net necrosis.

In other studies in Washington, the spread of leaf roll virus from rows of chronic leaf roll plants to adjacent plants started at weekly intervals from disease-free tubers, stopped abruptly during hot dry weather.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology

Shands, W. A., Webb, R. E., and Schultz, E. S. 1961. The importance of spring migrants of the buckthorn aphid in the spread of potato virus. Amer. Potato Jour. 38(4):114-6.

Shands, W. A., Wave, H. E., and Simpson, G. W. 1961. Observations on egg production by aphid pests of potato in Maine. Ann. Ent. Soc. Amer. 54(3):376-8.

Shands, W. A., and Simpson, G. W. 1962. The relationship of aphid abundance on potato plants to the specific gravity of the tubers. Amer. Potato Jour. 39(1):1-7.

Insecticidal and Cultural Control

Schopp, Ralph, Landis, B. J., and Hagel, G. T. 1961. Experiments with insecticides for control of the green peach aphid on potatoes. Jour. Econ. Ent. 54(5):1003-7.

Shands, W. A., Landis, B. J., and Reid, W. J., Jr. 1961. Controlling potato insects. USDA Farmers' Bulletin No. 2168.

Shands, W. A., Webb, R. E., and Schultz, E. S. 1962. Tests with milk and rice polish to prevent infection of Irish potato with virus Y transmitted by aphids. Amer. Potato Jour. 39(1):36-9.

Insecticide Residue Determinations

Dawsey, L. H., Woodham, D. W., and Lofgren, C. S. 1961. Heptachlor and heptachlor epoxide residues in truck crops. Jour. Econ. Ent. 54(6):1264-5.

Biological Control

Shands, W. A., Hall, I. M., and Simpson, G. W. 1962. Entomophthoraceous fungi attacking the potato aphid in northeastern Maine in 1960. Jour. Econ. Ent. 55(2):174-9.

General

Simpson, G. W., and Shands, W. A. 1962. Progress on insect and disease problems of potatoes in Maine...biology and control of aphids. Maine Agric. Expt. Sta. Bull. 602, p. 1-54.

AREA 3. DECIDUOUS FRUIT, TREE NUT, GRAPE AND BERRY INSECTS

Problem. Hundreds of insects and mites are pests of deciduous tree fruits, tree nuts, grapes and berries grown in the United States. Some occur regularly in destructive numbers over wide areas; others are sporadic or local in their occurrence. They cause direct damage to the crops and some of them transmit serious plant diseases. Since biological, cultural and other methods of combatting these pests have not been sufficiently effective, insecticides are depended on for their control. Continuing research is necessary to provide for changing needs. The development of resistance to insecticides in certain insects and mites, the occurrence of insecticide residues on fruits and berries, and the detrimental effect of insecticides on beneficial insects and on wildlife are complicating factors. There is a continuing need for more effective, more selective, economical, and safer insecticides; and for alternative types of insect control involving attractants, repellants, and growth-affecting materials, including chemosterilants. Less intensive spray programs to minimize residue problems and permit maximum effectiveness of insect parasites, predators, and diseases should be developed. More research is needed to develop integrated chemical-biological control programs to realize the maximum benefit of the respective control agents. Research is required to determine the role of insects in the transmission of important diseases affecting the production of these crops, to discover the insect and mite vectors of the diseases and to determine their host preferences, range, and habits. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases. A search should be initiated for insect-resistant germ plasm to be utilized in crop improvement programs, especially those relating to berries.

USDA PROGRAM

The Department has a long-term program involving entomologists, chemists, physiologists, and insect pathologists engaged in both basic studies and the solution of grower's problems. Research on pome and stone fruit insects and nuts is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Similar research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on grape insects, in cooperation with the Ohio Experiment Station, at Wooster, Ohio; and on berry insects at

Beltsville, Md.; and at Riverside, Calif., in cooperation with the California Experiment Station. Research on the role of insects and mites in the transmission of plant diseases is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on pecan insects, cooperative with the Florida Experiment Station, was discontinued at Monticello, Fla., in September 1961, and the resources utilized to strengthen the program on pecan insects at Shreveport, La. Cooperative work with the Wisconsin Experiment Station on the latent viruses of stone fruits was discontinued at Madison and Sturgeon Bay, Wis., in June 1962, and the funds shifted to insect vector studies headquartered at Riverside, Calif. Research on grape insects headquartered at Sandusky, Ohio, for many years was transferred to Wooster, Ohio, in January 1962.

Additional research (3.5 professional man-years) is in progress under a grant of P.L. 480 funds to the Institute of Pomology, Skiernieevice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites as influenced by acaricides and for studies on the biological control of aphids and scale insects on deciduous tree fruits and effects of pesticides on natural enemies. A portion of a grant of P.L. 480 funds to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, (10 professional man-years) for research on scale insects, fruit flies, and mites and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

The Federal scientific effort devoted to research in this area totals 24.9 professional man-years. Of this number 2.4 is devoted to basic biology and nutrition of insects; 6.0 to insecticidal control; 5.3 to insecticide residue determinations; 1.0 to biological control; 2.5 to insect sterility, attractants, and other new approaches to control; 0.7 to evaluation of equipment for insect detection and control; 5.5 to insect vectors of diseases; and 1.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 47.2 professional man-years divided among subheadings as follows: basic biology, physiology, and nutrition 6.8; insecticidal and cultural control 27.6; insecticide residues 4.4; biological control 2.3; insect sterility, attractants and other new approaches to control 0.5; evaluation of equipment for insect detection and control 1.4; varietal evaluation for insect resistance 0.4; and insect vectors of disease 3.8. All important deciduous fruit-producing States are conducting studies on the basic biology and insecticidal and

cultural control of injurious insects and mites. Most of the work on insecticide residues is being done in California, Oregon, Washington, Illinois, Pennsylvania, New York and Florida. Research on insects and mites attacking grapes and berries, primarily on insecticidal and cultural control and insecticide residues is conducted largely in New York, New Jersey, Pennsylvania, Kentucky, Florida, Michigan, Oregon, and California. Research on insect vectors of stone fruits is conducted in Wisconsin, California, Oregon, and Washington, on vectors of pear decline in California, and on vectors of berry diseases in New York. Research on the basic biology and insecticidal and cultural control of insects affecting pecans is carried on in Florida, Mississippi, and Texas, on almonds and walnuts in California and on filberts in Oregon.

Industry and other organizations, including chemical companies, also conduct research of interest and value on insect pests of deciduous fruits, tree nuts, and berries. Many chemical companies supply materials for testing and they also finance special studies, particularly research on residues. Orchard and berry growers cooperate with State and Federal Experiment Stations and with chemical companies by furnishing plantings, facilities, and materials for experiments. Estimated annual expenditures by industry are equivalent to approximately 15 professional man-years.

REPORT OF PROGRESS FOR U.S.D.A. AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

1. Deciduous Fruit and Nut Insects. Basic biological research was confined primarily to movement studies of the pear psylla and the seasonal development of the peach twig borer in Washington as a basis for improving the timing of spray applications. The pear psylla moves for considerable distances in the early spring and fall and to some extent as early as February and as late as November. Little or no movement occurs from about mid-April to mid-September. First-brood larvae of the peach twig borer appeared in orchards the first week in June and second-brood larvae about July 15. There was evidence that spring-brood moths move about in orchards very little and that first-brood moths move about extensively.

Ability to provide large numbers of insects at all seasons of the year is a prerequisite for an uninterrupted research program. This requires knowledge of the factors governing development of test species, particularly their environmental and nutritional requirements. In Indiana a satisfactory method for rearing the red-banded leaf roller continuously on an artificial medium has been developed and progress has been made on rearing the codling moth in a similar

manner. In cooperation with the Florida Experiment Station progress has been made on the development of an artificial rearing medium for the hickory shuckworm. Further work is necessary to adjust the nutritive elements in the modified wheat germ medium and to determine environmental conditions needed to induce egg-laying consistently and in numbers.

At Beltsville, Md., the mass production of Drosophila flies is being accomplished with a modification of a standard laboratory technique. About 2 million flies can now be produced with about the same labor costs formerly required to produce about 75,000.

At Wenatchee, Wash., studies of the effect of plant nutrition on mites showed that N, P and K deficiency in peach seedlings did not influence reproduction significantly except that fewer eggs were laid and mortality of adult mites was significantly greater on plants deficient in nitrogen. Foliar nutrients, such as boron, nitrogen, manganese chelates, zinc, and iron had no significant effect on egg laying and mite mortality. On the other hand egg laying was reduced significantly on apple seedlings deficient in N, P, and K but not on pear and on cherry only by a deficiency in P. Mortality of mites was also greater on pears deficient in P. No marked effect on egg laying and mortality of mites was found due to heavy residue in the soil of any of the more commonly used insecticides. In West Virginia leaf analyses over a 3-year period indicated a possible correlation between increases in leaf sugar content of apple leaves following use of DDT and Sevin and increases in mite populations.

2. Insect Vectors of Viruses. Knowledge of the overwintering habits of Homalodisca coagulata in Georgia has contributed materially to the research on control measures to prevent or retard spread of the phony peach virus. Similar studies of the vector Oncometopia undata have yet to reveal its overwintering habits. Attempts to find eggs, nymphs, or adults during January and February have been unsuccessful. In 1961 the first adults were collected early in March.

Comb-like tibial spines on four genera of Tettigellinae were studied in Georgia to determine their significance in the oviposition operation of phony peach virus vectors. These structures were most highly developed in the females of those species that cover the egg clusters with a waxy, chalk-like exudation produced by the females, particularly Oncometopia undata, O. nigricans, and Homalodisca insolita, and were similar in both males and females of species that do not produce the waxy substance, as Cuerna costalis and Aulacizes irrorata.

The need to separate the sexes of phony peach virus vectors before they become adults led to a search for suitable characters. Characters found in the fifth instar nymphs on structures that correspond to the plates of the genital capsule in adult males and the pygofers of adult females now permit accurate separation of the sexes in all three of the most important vectors.

Eriophyes insidiosus, the only known vector of peach mosaic virus, is present beyond the limits of peach mosaic distribution in eastern Texas at least to Georgia, but not in important peach-producing areas in northern California, the Pacific Northwest, or the Midwest. Recent special detection surveys in all peach-growing areas of northern California revealed its presence only as far north as San Luis Obispo County, an extension of only about 100 miles above its previous known range. Again the vector was not found in Washington or Oregon. In Colorado vector populations were extremely light, possibly because of the effect of sprays applied to control other insects.

An important outgrowth of the peach mosaic vector survey program has been the finding of a number of mites that closely resemble Eriophyes insidiosus on a variety of rosaceous trees or shrubs. At least eight such forms have been collected on as many kinds of common woody plants. Work in progress, as yet incomplete, seeks to determine whether certain of these mites may be (1) the mosaic vector species, or (2) species closely related to the mosaic vector and capable of transmitting peach mosaic virus. Comparative studies that were continued in California on the morphology of E. insidiosus and closely similar forms on pears, cherries, and other hosts, indicated that E. insidiosus and the similar form responsible for blistering on pear are distinct species, with the latter occurring in California, Oregon, Washington, Utah, Colorado, and Wisconsin. Likewise, the newly discovered vector of cherry mottle leaf virus, an eriophyid mite that resembles E. insidiosus closely, is also believed to be a distinct species. This mite vector was found on Prunus emarginata from northern California to Washington and on cultivated sweet cherry.

B. Insecticidal and Cultural Control

1. Codling Moth. The codling moth has a remarkable ability to become resistant to insecticides and to rebound from adverse conditions to maintain its status as a serious pest. DDT and, to a lesser extent, DDT-parathion sprays, are less effective than formerly in codling moth control on apples in many localities. In

some cases increased numbers of applications and/or amounts of insecticides per unit volume of spray have resulted in DDT harvest residues close to the tolerance of 7 p.p.m. This indicates that there is a limit to which growers can use increased dosages and number of applications to overcome the decreasing effectiveness of DDT. Research is therefore being continued on newly available insecticides for codling moth control.

Guthion alone or in combination with DDT or Sevin, or Sevin alone, is currently giving outstanding control. Addition of oil improved control with sprays containing Sevin but not with sprays containing Guthion or malathion. The extenders WARF and TD-244 failed to increase the effectiveness of DDT. In preliminary screening tests of newly available compounds Bayer 37344 and Stauffer 3413 showed promise for codling moth control in Indiana, Washington and West Virginia. In laboratory tests in Indiana and Washington Bayer 32,651, 41,831, 44646 and 46676; American Cyanamid EI-38023; General Chemical 3707; Hercules 7522H, 8717 and 9699; Hooker 1422; Menazon; Monsanto CP-40273 and 40294; Niagara 5943; Shell SD-8448; Stauffer R-1504 (Imidan), N-2310, N-2790, and N-2860; Upjohn 12927; and Zectran were found worthy of further trial. In a limited field trial the residual effectiveness of Zectran was superior to that of Bayer 37344, Imidan, Monsanto CP 40294 and American Cyanamid 43064 but not to that of Sevin. Bayer 37344 was superior against adult moths, being the only one of the materials to kill a high percentage after weathering 14 days.

Studies of Guthion residues on apples in Washington provided an explanation for its long period of effectiveness against the codling moth. Deposits disappeared at a faster rate from foliage than from fruit for about 2 weeks, and then declined to about the same level on both foliage and fruit at the end of 3 weeks. Subsequent losses were at about the same rate for up to 8 weeks. The loss on both fruit and foliage was about 50% after 3 weeks, about 67% after 4 weeks, with little loss occurring thereafter up to 8 weeks.

Results obtained in four cooperative tests with growers further demonstrated the effectiveness of a 2-application Guthion spray program for controlling the codling moth in the Yakima, Wash., area. In Indiana a three-year rotation program built around schedules containing organic phosphorus, chlorinated hydrocarbon, and carbamate insecticides maintained excellent control of the codling moth and other orchard insect and mite pests for the second year, although there were indications that Guthion is gradually becoming less effective in controlling mites.

2. Orchard Mites. No one approved miticide can be depended upon to control all species of mites in all orchards. This is an alarming situation brought about by the occurrence of insecticide-resistant strains of mites. An accelerated program of screening promising new insecticides, antibiotics, and other types of compounds that might inhibit mite activity and development has been activated along with studies to determine the influence of tree vitality, nutritional and hormone sprays, insecticides and fungicides on mite populations.

In screening tests of 150 or more newly available compounds in Indiana and Washington, the following were sufficiently promising to justify further trial: OW-9 (an analog of Aramite); American Cyanamid 43064, 43073, 43356 and 47031; Bayer 21,097, 25,141, 37,344, 41,522, and 45,432; Monsanto CP-40,272 and CP-40,273; Niagara 9044; Shell SD-3562 and SD-7438; Stauffer N-2860, R-1448, R-1504, R-1505, and R-1571; and Zectran. American Cyanamid EI-43064, 43356, and 47031; Bayer 25141; and Shell SD-3562 showed some promise as systemic insecticides.

In orchard tests in the Yakima Valley of Washington, Tedion, 1 pound 25% wettable powder and Kelthane, 2 pounds 18½% wettable powder per 100 gallons, usually in the first and third cover sprays, gave excellent control. Tedion was most effective in a preventive as contrasted to a suppressive schedule. Bayer 30686 (Eradex) and Shell SD-3562 gave excellent results but the latter material was markedly phytotoxic. Fair to poor results were obtained with 7 additional experimental materials.

In West Virginia prebloom applications were generally less effective than in other areas in maintaining European red mite control. In Indiana no one material tested in prebloom or early postbloom applications was outstanding for controlling mites on apples. Chlorbenside and Trithion included in the first and second cover sprays at half the single-application dosage were more effective than a single full-strength application at the pink stage of bud development. Ovex performed in a similar manner. No advantage accrued from using oil in combination with chlorbenside or Trithion in prebloom applications. Tedion was less effective in prebloom applications than chlorbenside or ovex but in postbloom applications it was highly effective. A pink bud application of chlorbenside or two applications of Tedion at the time of the first and second cover sprays proved more effective than a green tip application of oil. Indopol polybutene, a sticky material that traps mites, showed promise for use early in the season. Later its sticky nature may be objectionable and cause some injury. It was more

effective when applied after bloom than when applied before bloom. A root zone injection of phorate, 5 ounces per tree, at the time of the pink stage of bud development maintained excellent mite control.

In Ohio foliar sprays of DDT were followed by a much greater increase in populations of the European red mite on peach trees than occurred on trees receiving only ground sprays of DDT or DDT plus miticide. Superior type soluble dormant oils applied at dormant, delayed dormant and pink stages of tree development did not cause any noticeable injury to 10-year old Elberta peach trees and gave excellent control of mites throughout the season. In preliminary field tests on peaches Indopol polybutenes gave quite good control of mites in summer applications but not in a dormant spray. In Indiana two summer applications 7 days apart of Stauffer R-1504, Naugatuck OW-9, Niagara 9044, Zectran, ethion, Bayer 37344, and Trithion gave excellent control of mites whereas a single application failed to do so.

Use of dimethyl sulfoxide (DMSO) and other solvents was studied in Washington as aids in moving pesticides within plants by injection and for increasing the systemic action of pesticides applied in sprays or in pastes applied to the bark of trees. Most of the pesticides tested, including DDT, BHC, dieldrin, Sevin, Kelthane, Guthion and others not generally systemic, and a number of antibiotics moved to the leaves following injection of DMSO solutions into the tree trunks, as evidenced by phytotoxicity and effects on mites. There remains the need to work out practical methods of utilizing this discovery.

3. Plum Curculio. Methods for controlling this pest that will obviate the need for hazardous insecticides are desirable. Reports of the possible occurrence of parathion-resistant strains suggest the urgency of further insecticide studies.

In an orchard test in Georgia, Guthion was outstanding and superior to parathion-dimethoate or parathion-dieldrin split schedules, parathion, and Sevin. Dimethoate at 1 pound per 100 gallons was injurious to peach trees. At ½ pound Bayer 25154 was very effective but phytotoxic to peach foliage. Bayer 37344 was promising. Other promising materials caused no injury.

In laboratory screening tests of new insecticides Stauffer R-1504 and Monsanto CP 40294 were outstanding, and Bayer 37344 and 4183 very promising. Shell SD-3562, GC 3707, UC 8305 and UC 10854 deserve further evaluation. Other materials lacked residual value or both knock-down and residual value. In field tests on peaches in Indiana Guthion sprays and dusts and Sevin sprays gave excellent control of the plum curculio but a Sevin dust was less effective.

In cooperative field tests on plums in Ohio dieldrin, endrin, Guthion, and Sevin controlled the plum curculio in that order of effectiveness, ranging from 100% for dieldrin to 94.8% for Sevin. R-1504, which was superior to other experimental materials, and Zectran showed promise in controlling the plum curculio on plums but caused some injury. The polybutenes were completely ineffective and NIA 5767 was not promising.

In Georgia, soil applications of chlorinated hydrocarbon insecticides continued to control the plum curculio several years after application. Aldrin, dieldrin and heptachlor, with dosages of 2 to 4 pounds per acre, remained effective for 8 or 9 or more years. In an isolated orchard unsprayed since the soil was treated with aldrin in 1957 only 6.4% of the fruit was wormy at harvest in 1961. Cooperating entomologists in Ohio also reported good control with a soil application of aldrin or dieldrin. Preliminary results of tests of soil applications of aldrin or dieldrin in Indiana, Kentucky and New Jersey were poor. Type of formulation appeared to be unimportant for this usage. Bioassays of orchard soils from central Georgia peach orchards indicated that soil accumulations of insecticides from foliar sprays are becoming heavy enough to reduce the ability of curculio grubs to reach the adult stage and emerge.

4. Deciduous Tree Fruit Borers. Borers, particularly the peach tree and lesser peach borers, are among the most serious pests of stone fruits, weakening and shortening the life of infested trees.

In Georgia endrin and Thiodan were outstanding for control of these borers when used in trunk sprays to prevent peach tree borer damage to peaches. Dieldrin was only a little less effective and not improved by an extender, Arochlor 5460. Sevin was ineffective. The systemic insecticide phorate applied to the soil was also ineffective. In Indiana peach tree borer control with two applications of Thiodan was outstanding and a single application to the trunks and scaffold limbs also gave substantial but not complete reduction of the lesser peach tree borer infestation. In other tests endrin (one application), Guthion, Sevin, Thiodan, and a mixed dieldrin-Guthion schedule (3 applications) reduced a heavy infestation of the lesser peach tree borer by about 80%. A single application of dieldrin was ineffective. All treatments gave good control of a light infestation of the American plum borer in peach trees.

Phorate granules worked into the soil under the spread of peach trees in Georgia did not appear promising for controlling the peach tree borer, lesser peach tree borer, or shot-hole borer.

5. Pear Psylla. The problem of strains in the Pacific Northwest resistant to previously effective insecticides was further intensified during 1961 by the apparent occurrence for the first time of strains resistant to Guthion. Hitherto this material was considered to be the only really effective insecticide for summer use to control this insect.

In experimental plots at Yakima, Wash., 1½ pounds of 25% Guthion wettable powder per 100 gallons (600 gallons/acre) gave excellent control when three applications instead of the usual two were made, but at half that rate it failed to hold the population at an economic control level. Dilan, 1 pound of 50% wettable powder per 100 gallons, was equal to Guthion. Eradex (Bayer 30686) gave excellent control and Bayer 37344 and 36205 gave fair control. Bayer 32651 and 44646, Sevin, and phosphamidon were ineffective. Application of Guthion at several concentrations of from 1X (1½ pounds 25% WP/100/600 gallons/acre) to 8X resulted in excellent control of the pear psylla in all instances. There was practically no difference in the quantity of insecticide deposited by the different spray concentrations regardless of the type of sprayer used to apply them.

In laboratory screening tests at Wenatchee, Wash., Stauffer N-2230, 2404, and R-1504; Menazon, Hooker 1422; Bayer 36205 and 39007; and Niagara 5943 were the most promising of 20 compounds for controlling psylla nymphs, and Zectran and Shell 3562 were the only ones of 18 materials that were effective against adults. Apparent high resistance of the psylla to Guthion in orchards in Gleed, Wash., was confirmed in a laboratory evaluation.

6. Miscellaneous Insect Pests of Deciduous Tree Fruits. In studies at Kearneysville, W. Va., the root-infesting form of the woolly apple aphid caused malformations that render apple nursery stock unsaleable. Dimethoate, Thiodan, Hercules 5727 and Trithion applied to the tree trunks at the soil surface in each of the 2 years the trees were in nursery rows effected a highly significant reduction in the percentage of infested trees. Forty percent of untreated trees became infested. The most practical dosages remain to be determined. In another test dimethoate, Thiodan or Trithion, as used above to prevent infestation, was not able to bring an established infestation under control. This suggests it is easier to prevent than to suppress infestation.

The oriental fruit moth, long a serious pest of peaches and other fruits until brought under control with DDT, is now increasing in some areas. In Indiana, Guthion sprays and dusts and Sevin sprays gave excellent control on peaches but Sevin dusts were unsatisfactory. In Ohio, two applications of Sevin, 2 pounds 50% wettable powder per 100 gallons of spray containing phytomycin, glyodin, and ferbam, scorched the leaves of quince so much that no further applications were made.

The occurrence of TDE-resistant strains of the red-banded leaf roller has necessitated an expansion of research to find a material that can be used with or instead of TDE to maintain control. West Virginia tests showed that endrin must be applied before larvae reach the third instar to be effective; two and three applications beginning at petal fall were no more effective than one application only at petal fall. Bayer 22408 was slightly superior to endrin. In limited field tests in Indiana, Zectran and Bayer 37344 applied at petal fall were as effective as several of the recommended insecticides. TDE, lead arsenate, Guthion and endrin were effective against first-instar larvae. In laboratory tests Bayer 37344, Zectran, Guthion and endrin killed 100% of the first-instar larvae, TDE 91% and lead arsenate and dieldrin 82%. In Indiana, also, a related species of leaf roller, Platynota flavedana, was controlled effectively by a Sevin spray program. Sevin dust and Guthion spray and dust programs were not satisfactory. Finish of fruit in the spray plots was superior to that in the dust plots, primarily due to the use of sulfur as the fungicide with the dusts and captan with the sprays.

The apple maggot, the most serious pest of apples in some Northeastern and North Central apple-producing areas, cannot be controlled satisfactorily by present insecticides. In northern Ohio, traps showed that apple maggot flies were present from June 27 to about October 3, indicating the long period effective treatment must be maintained. Sticky board traps were superior to Medfly-type plastic traps for capturing flies attracted by the standard dibasic ammonium phosphate-protein hydrolysate bait. Catches were not consistently higher whether traps were placed in trees at a height of 15 feet or at a height of 7 feet. The lack of a satisfactory spray treatment has focused attention on attractants that might be used directly or indirectly in bait sprays for control. In cooperative screening tests in Ohio, no material was found equal to the standard, a mixture of diammonium phosphate and Staley's protein bait No. 2.

Scale insects devitalize deciduous fruit trees and may cause their death if left uncontrolled. Oil sprays most commonly recommended for scale insect control are not always fully effective against some species or when infestations of others are heavy. In Georgia parathion, parathion-dimethoate, and Sevin spray programs, as used to control the plum curculio, maintained the San Jose scale under control and a Guthion program was only slightly less effective. Parathion, malathion, Guthion, Sevin and dimethoate, whether applied during the dormant season or later, were not effective against the white peach scale.

Forbes scale has largely replaced San Jose scale as an important pest in many orchards in the Midwest and East, so much so that it is desirable to know the value of new insecticides for its control. In 1960 field spray plots on apples in Indiana a petal fall and seven cover sprays of Delnav, DDT, Bayer 22408 and 29493, and SD-5533 did not prevent an increase in the infestation of Forbes scale. Guthion and Sevin held populations to a low level, as previously.

The feeding of sucking bugs causes peaches to become deformed. The number and variety of species involved and the length of the period they are active make their control difficult, especially since no one available insecticide is effective against all species. The most effective treatment known (a dieldrin-Guthion combination) can be expected to reduce injury only by about 63%. In continuing cooperative research with the Ohio Experiment Station, Indopol polybutene was superior to Zectran, NIA 5767, and R-1504, but the percentage of the crop injured was reduced by only 63.3%. In another case endrin was superior to Sevin, Guthion, and dieldrin but reduced plant bug populations by only 75%. In still another instance dieldrin and Guthion alone and in combination were superior to Thiodan alone or with Guthion but control was below commercial standards.

Several species of aphids are well-known, injurious pests of deciduous fruits. A number of insecticides are highly effective in reducing damaging populations but lack the residual qualities needed to prevent reinfestation in a short time. A more persistent aphicide or another type of treatment is needed. In Washington Niagara 5943, Bayer 44646, Upjohn 12927, Stauffer R-3413, and Zectran were most promising of 24 experimental insecticides evaluated for controlling the apple aphid and Stauffer compounds N-2404, B-8760, N-3051, N-2230 and B-8778 and Niagara 5943 were most promising of 10 compounds evaluated for controlling the green peach aphid.

The cherry fruit flies, Rhagoletis cingulata and R. fausta, continue as important pests of cherries because of their occurrence in maximum numbers as the cherries reach maturity. This imposes a residue limitation on the insecticides that can be used in their control. In Ohio, the newly developed standard bait of dibasic ammonium phosphate with Staley's protein insecticide bait No. 2 was superior to the previous standard, ammonium carbonate, accounting for 77% of the fruit flies captured. This bait attracted more adults when exposed in combination with sticky board traps than when exposed in Medfly plastic traps. Two field tests of malathion bait sprays, so effective against certain other fruit flies, gave discouraging results, permitting 5% or more of the cherries to become infested. Near perfect control is needed, particularly for cherries destined for commercial canneries.

Sevin, an insecticide effective against a wide range of deciduous fruit insects, has reduced the set of apples when used in the petal fall and early cover sprays. In a test in Indiana, it had this same effect in 1961 when used in the pink-bud period of apple development, reducing set 60% on Jonathan Clark-dwarf trees and 23% on Starking Clark-dwarf trees. On peaches, there was little or no effect on set.

For years injury caused by the feeding of nymphs of the periodical cicada on the roots of mature apple trees was not recognized. Recently it has been found that such feeding may cause the decline and ultimate death of trees. Soil applications of phorate and Sevin failed to control the cicada in a heavily infested apple orchard in Indiana.

Renewed efforts have been made to find combinations of insecticides compatible with recommended fungicides for use in controlling scale insects, mites and aphids before bloom of apples. In tests of possible effective combinations in Indiana, mixtures of oil sprays and the fungicide, dodine (Cyprex), were compatible but unstable when wettable powder formulations containing Guthion, malathion, Sevin, Trithion, Genite, BHC, Niacide, ferbam, or zineb were included. Emulsifiable concentrates, containing Guthion, demeton, and dimethoate, were readily mixed in sprays with oil and dodine, but two formulations of emulsifiable malathion were not satisfactory when combined with the oil and dodine.

7. Pecan Insects. Work was continued on the development of methods of preventing or suppressing insect and mite damage to pecans in cooperation with the Florida Experiment Station (formal cooperation discontinued September 30, 1961) and in Georgia and Louisiana. Staffing for an expanded program in Georgia was completed and facilities improved.

The hickory shuckworm received major attention in Florida and Georgia in a continuing effort to find a satisfactory treatment for this difficult pest. In field spray tests in Florida, EPN and Guthion gave excellent control of a light infestation of the shuckworm regardless of the type of formulation, wettable powder or emulsifiable concentrate, when used in a 3-application schedule. Dosage, likewise, was not important within the range tested. In one experiment in Georgia, Thiodan and Phosdrin wettable powders and Guthion emulsifiable concentrate were as effective as EPN and Guthion wettable powders. Differences in control were not significant and the quality of the nuts was good in all cases. In a second experiment EPN emulsifiable concentrate and EPN wettable powder alone and with a tung oil sticker reduced shuckworm infestation to a low level and were superior to Diazinon, which was not very effective. The quality of nuts harvested from the Diazinon plot was equal to that of nuts from the EPN plots.

The pecan nut casebearer, at times the number one pest of pecans, was uncommonly abundant in Florida and in portions of the more western part of the pecan belt. In Louisiana, conventional ground applications of recommended insecticides were generally superior to aircraft applications.

The pecan leaf casebearer, for years a minor pest, reached damaging population levels in many orchards in the Southeast. In Georgia, aerial applications of a 10% malathion dust at 20 pounds per acre gave effective control of a light infestation. However, the minimum effective dosage remains to be determined. EPN, Diazinon, and Bayer 29493 at 2 pounds of formulated wettable powder per 100 gallons in 3 applications at 2-week intervals beginning August 11 gave almost complete control of a heavy infestation. The indications are that summer applications may give more dependable control than spring applications.

The pecan weevil occurs sporadically throughout the area in which pecans are grown, and in the absence of control measures, may cause serious crop losses. When pecan orchards are used for pasture, there is need for insecticides that will leave short-lived, less hazardous residues on the orchard cover than DDT or toxaphene, the currently recommended materials. Results of tests of soil insecticides, heptachlor, aldrin, and dieldrin, were inconclusive and need confirmation in further experiments. In a test in Arkansas, methyl parathion at the rate of 1½ pounds in 10 gallons spray per acre, gave poor kill of the pecan weevil but excellent control of the walnut caterpillar.

The pecan phylloxera, a primary pest of pecans in southwestern U. S., continued to spread and to cause severe damage in infested orchards in which it was not controlled. In Louisiana indications were obtained that aircraft may be utilized for the application of insecticides for control as well as ground machines. An aerial application of BHC, $1\frac{1}{4}$ to $1\frac{1}{2}$ pounds gamma BHC in 15 gallons spray per acre, prevented heavy losses of foliage due to phylloxera damage. Malathion at 3.2 pounds per acre was slightly less effective than BHC.

There is an urgent need for data on the effect of aphid feeding and of the honey dew secreted by some species on the productiveness of pecans. Continued cooperative studies with the Crops Research Division in Louisiana have thus far yielded little information because of inability to control the black-margined aphid. Demeton and schradan, the better available insecticides, have failed to give adequate control of this aphid. Against another species, the black pecan aphid, an aerial application of 0.43 pound demeton in 5 gallons of spray per acre gave much faster kill than one of 0.86 pound parathion per acre; after approximately 24 hours there were very few live aphids in either plot.

In Louisiana, a little-known leafminer, Nepticula sp., reached outbreak proportions in 1960 and reappeared in numbers in 1961. A dilute parathion spray, 2 pounds 15% wettable powder per 100 gallons, was adequate to prevent serious damage.

A spittlebug, Clastoptera achatina, an occasional pest of pecans in the Mississippi Valley, became unusually numerous locally in Louisiana in 1961. Thorough application of a dilute spray of 2 pounds 10% gamma BHC or 15% parathion wettable powder per 100 gallons gave good control of nymphs. In other tests Guthion and Thiodan were also effective against the nymphs.

The mite, Tetranychus hicoriae, is a continuing problem in pecan orchards. In Louisiana, Kelthane, 2 pounds of an $18\frac{1}{2}$% wettable powder per 100 gallons, was as effective as the standard parathion-wettable sulfur spray.

8. Grape Insects. In Ohio the grape berry moth, long the most serious pest of eastern-type grapes, was controlled effectively with Sevin 85% wettable powder at 3.4 pounds per acre. Sevin 85% wettable powder and Sevin flowable formulations were equally effective. A commercial spreader-sticker, a Triton B-1956-kerosene wetter, and 1 or 2% of a tung oil sticker were about equally effective in increasing deposits of Sevin wettable powder but residues decreased very little over an 8-day period whether Sevin

was used alone or with the wetters and stickers. There was no significant difference in control obtained with Guthion in a spray combination that included a copper fungicide with or without hydrated lime. Standard DDT-parathion and DDT-parathion-malathion schedules continued to give good control.

There have been indications of the occurrence of parathion-resistant strains of the two-spotted spider mite in some Ohio vineyards. In a comparative test of Kelthane and parathion following two seasons in which parathion was not used, both materials gave excellent control.

Several species of gall-forming insects occur in vineyards in tremendous numbers, usually in limited areas, causing great concern. Satisfactory methods of control are not available for most species concerned. Guthion, 18 ounces per acre, in a 5-application spray program failed to control the grape tomato gall but soil applications of phorate at 20 or 40 pounds per acre appeared promising. In an experiment in which untreated vines were heavily infested in 1960, only a few galls appeared on the phorate treated vines; considerable residue was found in the foliage but none in the berries at harvest. No infestation occurred on untreated vines in this vineyard in 1961 or on 1960 treated vines that were untreated or retreated in 1961; however, a considerable amount of phorate was found in the foliage in 1961 on vines treated in 1960.

The grape cane girdler is sufficiently injurious at times to create a need for an effective method of control. No such method has been available. In Ohio Guthion (3 applications) applied to control the grape tomato gall gave a very high degree of control of the grape cane girdler but Sevin (2 applications) applied to control the grape berry moth was ineffective against the grape cane girdler.

Work on vectors of Pierce's disease of grapes in Georgia was concluded with the publication of a report on the insects found to be vectors.

9. Berry Insects. In California, phorate and Di-syston continued to give good control of spider mites on strawberries when used as systemics in the soil before planting. Applied at 1 and 2 pounds per acre, respectively, in December these materials controlled the mites through the following May. Also in California, Kelthane applied to the foliage of strawberry continued to give good control of spider mites and was superior to other materials tested.

At Beltsville, Md., the role of lygus bugs in causing damage to strawberries known as "button berries" was confirmed; also, that insecticides detrimental to pollinating insects should not be applied for lygus bug control after strawberries begin to bloom.

10. Drosophila. Drosophila spp. are often nuisance pests in and around fruit and berry plantings and processing plants. In field tests in Ohio a Sevin-malathion spray applied 3 days prior to harvest effected about 75% reduction in Drosophila infestation in harvested grapes and pyrethrum, malathion, Sevin and Diazinon dusts reduced infestation appreciably. However, 3.4 pounds Sevin per acre failed to reduce a Drosophila infestation appreciably when large numbers of bird-damaged and cracked grape berries were present. Grape pomace spread in the vineyard immediately after pressing did not contribute to the Drosophila problem, apparently drying out too rapidly to serve as a suitable breeding medium.

C. Insecticide Residue Determinations

1. Deciduous Tree Fruits and Nuts. In Indiana apples were sprayed with Sevin, Guthion, DDT, or malathion in combination with captan and with or without 2% Indopol polybutene H-100. The polybutene had no effect on original deposits of DDT and Guthion, but decreased amounts of Sevin and malathion deposited. The persistence of DDT and Sevin was increased by the polybutene, but there was little effect on the persistence of Guthion and malathion.

Residue studies of some of the newer insecticides in Indiana, Ohio, Maryland, Kentucky, Washington and West Virginia showed (1) that a measurable residue may remain at harvest if endrin is used after apples are present on the trees. Since endrin is approved for use on apples on a no residue basis, it should not be applied in cover spray applications to bearing trees with a crop; (2) harvest residues of Tedion on apples were well below the established tolerance of 2 p.p.m. from applications 7 to 28 days before harvest in Indiana and on apples sprayed according to recommendations in Washington; (3) in Indiana harvest residues of Kelthane and Tedion on peaches sprayed 7 days before harvest were well below the established tolerances of 10 and 7 p.p.m., respectively, while a Sevin spray applied 1 day before harvest resulted in a harvest residue slightly in excess of the approved tolerance of 10 p.p.m. Residues from application of a Sevin dust did not exceed 1 p.p.m. Brushing peaches to improve their appearance reduced harvest residues about 50%; (4) residues at harvest resulting from application of Sevin to cherries in Ohio 0 to 9 days before harvest were well below the tolerance of 10 p.p.m. on or before the second day after application; and (5) harvest residues of Thiodan on peaches resulting from recommended usage for borer control were well below the established tolerance of 2 p.p.m.

Analyses in Indiana indicated that certain systemic insecticides may occur in leaves of fruits in sufficient quantity to control aphids and mites without appearing in the fruit in significant amounts. Significant residues of phorate were found in the foliage of grapes but none in berries from vines receiving 10 pounds phorate per acre as a soil treatment. Berries from vines receiving 20 pounds per acre had a small amount in them at harvest, 1.5 p.p.m. When phorate emulsion concentrate was injected into the soil about apple trees, there was a maximum concentration of the insecticide in the foliage after about one month. Phorate from a granular formulation did not reach maximum concentrations in the trees until August. Di-syston reached its maximum concentration in foliage at the end of May. Fruit samples collected in July, August, and September had only zero to 0.1 p.p.m. of residue.

D. Biological Control

1. Deciduous Fruit and Tree Nut Insects. Problems associated with the use of insecticides have increased interest in other methods of controlling insect pests. Special attention has been given to the evaluation of insect pathogens. In large scale tests initiated in Indiana and West Virginia in the fall of 1960, the DD-136 nematode program failed to protect a high percentage of the apples from codling moth damage in 1961 even though the ability of this organism to kill a high percentage of the worms in bands on the tree trunks was confirmed. In West Virginia, parasitization of larvae in bands was unusually high. Susceptibility of the organism to dryness seems to be responsible for its failure in control. The organism also failed in a test on periodical cicada nymphs in the soil.

In Indiana, the pathogens, Bacillus thuringiensis and B. soto, were ineffective in codling moth control but in Georgia B. thuringiensis showed promise for use to control the peach tree borer. In the spring of 1961 not a single live borer was found in trees treated with this material twice a month for six months from May to October, 1960, and only 2 per tree were found following 6 monthly treatments during the same period. Trees receiving a single application of the pathogen averaged 14.2 borers each and untreated trees 19.3.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Deciduous Fruit and Tree Nut Insects. Sterilization of insect populations by radiation or with chemicals is a possible approach to control or eradication of insects that can be sterilized without behavior breakdown. In Washington, the codling moth proved to

be most susceptible to sterilization by gamma radiation without affecting its vigor when exposed in the pupal stage immediately before adult emergence. Exposure to different dosages from 20,000 to 40,000 r (roentgens) had varied effects on adult emergence and fertility of males. Each rate of exposure within this range caused complete sterility of females as determined by cross breeding with non-treated males. None of the eggs from non-treated females crossed with males treated with 40,000 r produced moths while a small percentage crossed with males receiving lesser exposures did so.

In another test of gamma radiation Drosophila melanogaster females mated with males exposed to 5 kr in the larval stage, 10 to 20 kr in the pupal stage, or 20 kr in the adult stage in Maryland deposited the normal number of eggs, none of which hatched. At the same dosages females treated in the pupal or adult stage and mated with untreated males produced few or no eggs and females irradiated in the larval stage produced fertile eggs but in smaller numbers. The longevity of males or females irradiated in the pupal or adult stage was not affected while the longevity of those irradiated in the larval stage was reduced. In multiple mating tests untreated female flies mated with irradiated males produced sterile eggs until a subsequent mating with untreated males after which they produced viable eggs that developed into adults. Untreated female flies mated with normal males produced viable eggs and continued to do so after a subsequent mating with irradiated males. In limited tests sterile and normal males in the ratio of 5 to 1 gave 55 to 60% reductions of the progeny of normal females with which they mated.

In Washington favorable results were obtained from dipping codling moth eggs and pupae in solutions of chemical sterilants, but observations made thus far have been exploratory.

In Georgia no olfactory sexual attraction between the sexes of the plum curculio was observed, but in preliminary tests with the chemosterilant aphoxide (ENT-24915) plum curculio males allowed to feed for 3 days on treated apples were nearly completely sterile. External applications of aphoxide to adults and larvae failed to produce sterility. Females that fed on a 1% solution of aphoxide produced viable eggs. ENT-26316 also had a chemosterilant effect on the plum curculio but less than aphoxide.

In Indiana 25 chemosterilants tested against the two-spotted spider mite in the laboratory exhibited different modes of action. ENT-25297, 32149, 50004, and 50005 were effective when used in foliar sprays, ENT-50003 and 50005 were effective as systemic insecticides, and ENT 3582, 17185, 25297, 25301, 32149, 5003, 5004, and 5005 depressed reproduction.

Further studies at Wenatchee, Wash., of Acti-dione, an antibiotic, showed that it controls mites by a systemic action through the plants that inhibits egg laying. Several derivatives of Acti-dione performed in a similar manner but to a much lesser extent. A number of antibiotics used in medicine and anti-tumor and viricidal drugs tested were ineffective. Five coded glutarimide compounds, ENT 26258, 26259, 26260, 26261, and 26262, inhibited egg laying by mites, but to a lesser extent than Acti-dione. The antibiotics Streptovitacin A and Cytovirin were equal to Acti-dione in activity against mites. Mycostatin, Amphotericin, and Hygromycin B inhibited egg laying but to a lesser extent than Acti-dione. Most of the antibiotics that affected egg laying caused some adult mortality. Acti-dione is too toxic to apple and pear trees to permit its use in field tests. On mature peach trees this material had only a slight injurious effect on leaf buds at concentrations of 50 and 100 p.p.m. and gave fair control of mites for about 4 weeks.

In further studies at Wenatchee of the effect of antibiotics on reproduction and mortality of the apple aphid and green peach aphid, there was not much evidence of any action on ovarian and embryonic development but relatively low concentrations of a few of the materials, such as Cytovirin, cycloheximide, and Streptovitacin A, caused considerable mortality of adults.

In Maryland a 1% apholate bait gave promising results in producing sterility in Drosophila adults. In limited tests no progeny developed from treated females mated with treated males and very few developed from untreated females mated with treated males. Apholate-fed females produced very few eggs; whereas normal females mated with treated males laid a normal number of eggs of which very few hatched. Longevity of males did not seem to be affected by the treatment.

Successful efforts of studies of sex and chemical sterilants for the gypsy moth and subtropical fruit flies has stimulated a search for similar attractants for some of the major insect pests of deciduous tree fruits and nuts.

In Indiana no response was obtained when codling moth adults were exposed in the greenhouse and field to preparations of extracts of virgin female or male moths or to similar preparations from the gypsy moth or the synthetic gypsy moth attractant. In Georgia extracts prepared from the female hickory shuckworm and plum curculios were unattractive to natural populations. In Ohio similar negative results were obtained with extracts from male and female abdomens and from heads and thoraces of the apple maggot.

The presence of a peach tree borer sex attractant was indicated by Georgia studies. Male borer moths exhibited definite responses to an extract prepared from abdomens of female moths but not to extracts from other body segments. In the initial tests live females were more attractive than the extract from female abdomens. This suggests the possibility that more attractive extracts can be developed. In Indiana promising results were obtained in preliminary studies with the lesser peach tree borer. Four traps, each baited with a virgin female moth, attracted an average of 20 male moths.

Special efforts have been made in Florida, in cooperation with the Florida Experiment Station, to find a chemical attractant that can be used to control the hickory shuckworm. Exposure of about 100 candidate chemical attractants in 1961 and 1962 failed to reveal one with any promise.

In Indiana ammonium carbonate was more efficient than ammonium phosphate as a lure for the walnut husk fly. Pyridine was effective as a lure but evaporated rapidly. Limited trap operations in northern Ohio showed that the adult flies were active from July 18 to October 6. This fly is a widespread pest of black walnuts for which better control measures are needed. An attractant that could be used effectively in a bait spray would be invaluable.

In preliminary laboratory tests in Maryland a sample of ENT 400-F Super from the Northern Utilization Research and Development Division showed promise as an attractant for Drosophila melanogaster adults. Although about 3500 samples have been tested (1300 in 1960 and 260 in 1961), this is the first one to compare consistently and favorably with the standard.

F. Evaluation of Equipment for Insect Detection and Control

1. Deciduous Fruit Insects. In Washington the deposit of Guthion at 12 pounds of 15% wettable powder per acre in 800 (standard), 400, 200, 100, or 50 gallons of water applied with a conventional air-blast sprayer and in 60 gallons of water with a Turbo-Mist concentrate sprayer was practically the same at the 6- and 12-foot levels in trees but at the 18-foot level it decreased to some extent with increase in spray concentration. There were no codling moth injured fruits in any of the plots at harvesttime and no differences in codling moth control were found by biological assay of residues at the 12-foot level due to spray concentrations or differences in the machines with which the sprays were applied.

In Washington application of a program of 8 pounds of 25% Tedion wettable powder in the first cover spray and 16 pounds of 18½% Kelthane wettable powder in the third cover spray at rates of 800, 400, 200, 100, and 50 gallons of spray per acre with an air-blast sprayer or at 13.3 X in 60 gallons of water per acre with a Turbo-Mist concentrate sprayer maintained mites under control at the 6- and 12-foot tree levels but not at the 18-foot level at 2X (400 gallons per acre) or greater concentrations.

2. Pecan Insects. In Georgia an aircraft application of malathion, 20 pounds of 10% dust per acre, reduced infestation of the first-generation nut casebearer about two-thirds. In Louisiana, when application was made with a Speedsprayer, Guthion gave excellent control of first-generation nut casebearer larvae and was more effective than Thiodan, Trithion, or ethion, each of which gave good control. In experiments in Louisiana results of applications with aircraft for nut casebearer control were inferior to those obtained with ground sprayers but good enough to justify use of aircraft for control of this insect in emergency situations or when other types of application equipment are not available. In these tests malathion at 4 pounds and Guthion at 1.1 pounds per acre were about equally effective and superior to parathion at 1.7 pounds per acre. In general airplane applications of concentrated insecticides were superior to airplane applications of dust formulations.

3. Grape Insects. In tests in Ohio to compare grape sprayers and spraying procedures residue determinations showed that insecticide deposits were not significantly different whether application was made with a hooded-boom or spar-type sprayer or whether it was made with a hooded-boom type sprayer delivering 200 gallons of spray per acre and travelling at 3 miles per hour or when the sprayer delivered 300 gallons per acre travelling at 2 miles per hour.

In continuing tests of an experimental concentrate sprayer increasing the number of nozzles from 2 to 4 and the volume of spray applied per acre did not increase deposits comparable to those obtained with a hooded-boom sprayer. Deposits were 1.8 to 2.4 times greater with the latter machine.

4. Drosophila. Field studies of Drosophila populations in Maryland showed the need for a marker to identify field-released chemosterilant-treated adults. Seven water-soluble fluorescent biological stains sprayed on laboratory-reared D. melanogaster adults at 1% strength left residues that could be readily seen under a binocular microscope for at least two weeks. The best

stain tested was rhodamine B. The use of biological stains as markers provides a simple and inexpensive method of identifying field-released insects in population studies. In 1961 marked D. melanogaster adults were caught 2 miles from the point of release.

G. Insect Vectors of Diseases

Insects and mites are primary vectors of many virus diseases. Knowledge of the vectors serves as a basis for developing methods of preventing or suppressing spread and for determining the host range and other important characteristics of viruses.

1. Phony Peach Virus. Phony peach virus vector surveys were continued in the Fort Valley and Barney, Ga., study areas from March through October, mainly in support of vector control activities. These showed that populations of the primary vector, Homalodisca coagulata, were at a low level in 1960 and 1961 but increased sharply in the Barney area in 1962. Oncometopia undata was slightly more abundant in 1961 than in 1960.

Twenty transmission tests initiated in Georgia in 1958 to determine the role of dehorned phony virus infected trees as sources of inoculum for spread of the virus by its principal insect vector, Homalodisca coagulata, resulted in 1 additional positive transmission identified in 1961 following 2 positive cases in 1960. Such trees are a danger to spread if not removed promptly. Transmission tests with Oncometopia nigricans, until 1960 a synonym of O. undata, an important vector of the phony virus, and Aulacizes irrorata, in 1960 and 1961, and with Graphocephala coccinea in 1960 yielded no positive results in 1960 or 1961 but O. nigricans appears to have effected transmission in one instance recorded in 1962.

The results of vector control experiments initiated in 1958, in cooperation with the Plant Pest Control Division and Georgia Department of Entomology and continued annually to date, show that a two-spray program of 1½ pounds of DDT per acre applied by airplane to mixed woods where the principal phony peach virus vectors hibernate near peach orchards may be effective. Favorable results reported in 1960 were confirmed by the results obtained in 1961. Initially there appeared to be a direct relationship between the reductions of the vector populations and reductions in the expected number of diseased trees. However, in the Barney, Ga., area in 1962 the incidence of spread of the virus was disappointingly high. The data indicate that the first application should be made the first week in April and the second 30 days later. The

1961 tests were redesigned to measure the effect of reducing the amount of DDT per acre to 1 pound. This may account for the increase in the vector population in 1962.

The systemic insecticide Di-syston killed vectors of the phony peach virus for two seasons in Georgia when applied to the soil about the base of young peach trees at 50, 100, 150, 200, or 300 grams of 10% granules per tree in tests initiated in 1960 and continued in 1961. The vectors ingested lethal doses of the insecticide within 2 to 3 hours of feeding on treated trees and 100% mortality usually resulted in 1 to 3 days until effectiveness declined. Four-year-old Elberta trees showed no phytotoxicity after receiving 100, 200, or 300 grams of the insecticide per tree. Small June-bud Keystone trees were severely damaged with 100 grams per tree. These results suggest a possible treatment for protecting young peach trees from the phony peach virus during the period they are most susceptible to infection.

2. Peach Mosaic Virus. There is still no indication that any insect or any other species of mite other than E. insidiosus is a vector of peach mosaic virus. In one set of 22 experiments in California, E. insidiosus mites from trees infected with both peach mosaic and ring spot viruses transmitted the former but not the latter virus. This provided several ring spot free cultures of peach mosaic virus for Crops Research Division workers. In a second set of 15 experiments E. insidiosus failed to transmit a mild mosaic-like virus commonly encountered in western peaches, including northern California. Thirteen parallel transfers from known mosaic-infected trees gave transmission, giving good reason to conclude that the new mild mosaic-like virus is not peach mosaic. In still other transmission tests apple and pear failed to become infected, a strong indication that these fruits are not susceptible to the peach mosaic virus.

A simple method of rearing E. insidiosus in large numbers is urgently needed to provide specimens for basic studies of the peach mosiac virus. Attempts were continued with varying concentrations of plant hormones to produce young peach seedlings with retarded buds of the type required by this mite for good development. Use of maleic acid hydrazide and parachlorophenoxy acetic acid at concentrations of 1 to 10,000 or weaker provided peach seedlings that superficially had the required characteristics. Thus far, however, repeated transfers of mites to such trees have not been followed by prompt establishment.

In 1961 and 1962 all host trees, 1,643 trees on 19 properties, in an isolated mosaic-infected area in California were sprayed with Diazinon, 2 pounds of 25% wettable powder per 100 gallons, early in May to determine the value of such a treatment in suppressing spread of the virus. Samples of 10 buds from each of two trees heavily infested with mites yielded 1,200 and 1,350 living mites before spraying; similar samples yielded 1 live and 1,100 dead mites on one tree and 2 live and 1,150 dead mites on the other tree 38 days after spraying. At least three years will be required to obtain a valid indication of the effect of the treatment on virus spread.

In preliminary control experiments a fall application of insecticides was about 10% less effective than a spring application in controlling E. insidiosus. Reductions in infestation ranged from 91% for Di-syston, 90% for Schradan, 88% for Diazinon, 83% for parathion, 77% for Phosdrin to 74% for demeton.

3. Latent Group of Stone Fruit Viruses (ring spot, sour cherry yellows, etc.) Because of the increasing interest in the hypothesis that natural spread of ring spot virus may occur through virus-infected pollen, with or without the aid of insects, the cooperative vector search program in Oregon has been reoriented to stress the relationships of ring spot virus to infective pollen and to pollen dispersal. Forty-five vector tests were initiated with 2 strains of ring spot virus, a standard "R-31" and a recurrent ring spot strain, utilizing 4 species of aphids. Experiments were designed to test persistent and non-persistent types of transmission and involved manipulations utilizing sour cherry and herbaceous hosts. Positive results were not obtained in cucurbits; readings in sour cherry will come later.

In cooperative studies in Wisconsin, 100 2-year old virus-free Montmorency cherry trees were planted in four distinct environments in relation to degree of exposure to sour cherry yellows infected plants to study natural spread and the insects found associated with it. Blossoms will be removed each spring as long as practical. There was also carried out in Wisconsin a series of tests with potted trees to determine season of spread of the sour cherry yellows virus, groups of trees being exposed at different periods during the season; and a search was made for vectors of sour cherry yellows virus involving 110 transmission tests with three species of aphids. During the season there were reactions in 14 trees. Careful indexing in 1962 will be carried out to determine if they represent transmission of sour cherry yellows.

4. Miscellaneous Stone Fruit Virus Diseases. The incidence of occurrence of peach rosette, a rapid tree-killing virus, appears to be increasing in Georgia, prompting increased attention to possible insect vectors. The results of 117 transmission tests with about 18 species of Homoptera, mostly leafhoppers associated with natural spread areas, initiated in 1961 are not yet available.

In Washington a new species of eriophyid mite from Prunus emarginata effected 12 successful transmissions of the cherry mottle leaf virus in 21 tests made by the Riverside, Calif., staff. Results of 303 confirmatory tests initiated by Washington Experiment Station cooperators in 1961 should be available before the end of 1962. Transmission tests are also underway with a second eriophyid mite, E. prunidemissa, from P. demissa.

The little cherry virus (sometimes referred to as K and S virus), which is widespread in flowering cherries, is a threat to commercial cherry production, as has been demonstrated by its rapid spread in British Columbia. In Oregon in 1960 transmission tests were initiated with four species of leafhoppers utilizing Sam cherry and several herbaceous hosts, the latter in a search for a host to facilitate future transmission tests. In 1961, 16 additional tests were initiated with three leafhopper species in a further effort to discover a succulent host. Conspicuous symptoms were observed in one celery plant from tests with Macrosteles fascifrons but confirmatory tests are needed to establish transmission.

5. Pear Decline. The growing acceptance of the belief that a virus may be associated with pear decline and the seriousness of spread in California and other western States prompted vector studies in close cooperation with Federal and State research workers in other disciplines in California in initiating an all inclusive study of the pear decline problem. Initial efforts to determine the possible role of insects and mites in the spread of this disorder were centered on eriophyid mites, logical suspects not being given attention by cooperators. A total of 172 test trees received 52,250 mites of two species separately and in combination. The test trees are being held for possible development of symptoms.

The coincidence of spread of the pear psylla and subsequent occurrence of pear decline in the West casts suspicion on this psylla as contributing to the spread of pear decline. Recent work by the Washington Experiment Station suggests that the psylla carries a toxin into pear trees that creates a condition similar

to pear decline. Surveys for pear psylla in areas where it was not previously known to occur in southern California resulted in its discovery in San Diego County, an area where pear decline appeared to occur in advance of the psylla. The limited known distribution of the psylla in San Diego County suggests its recent introduction. Limited transmission tests utilizing the pear psylla have not yet been completed.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Pollard, H. N. and Kaloostian, G. H. 1961. Overwintering habits of Homalodisca coagulata (Say), the principal natural vector of phony peach disease virus. Jour. Econ. Ent. 54(4): 810-811.

Pollard, H. N. 1962. Sex determination of fifth-instar nymphs of leafhoppers (Cicadellidae, Proconiini). Jour. Econ. Ent. 55(1): 141.

Insecticidal and Cultural Control

Brunson, M. H. and Dean, F. P. 1961. The residual quality of some insecticides used on apple to control codling moth. Proc. Fifty-sixth Ann. Meeting Wash. State Hort. Assoc. pp. 38-39.

Campbell, Roy E. and Taylor, E. A. 1962. Strawberry insects--how to control them. U.S.D.A. FB 2184.

Cleveland, M. L. 1960. Laboratory rearing and testing techniques for the two-spotted spider mite. Proc. North Cent. Br., E.S.A., 15: 66-67.

Cleveland, M. L. 1960. Methods of determining orchard mite populations. Proc. North Cent. Br., E.S.A., 15: 50-51.

Cleveland, M. L. 1960. Soil injection as a means of applying systemic acaricides to fruit trees. Jour. Econ. Ent. 53(1): 144-146.

Cleveland, M. L. 1961. Mite control investigations in 1960. Proc. North Cent. Br., E.S.A. 16: 68-70.

Cleveland, M. L. and Hamilton, D. W. 1961. Mite control. Amer. Fruit Grower 81(5): 34, 36.

Dean, F. P. 1961. The comparative effectiveness of several acaricides against the Mcdaniel mite on apple. Proc. Fifty-sixth Ann. Meeting Wash. State Hort. Assoc. pp. 35-37.

Hamilton, D. W. 1960. Effect of Sevin on the set of apples. Proc. North Cent. Br., E.S.A., 15: 48-49.

Hamilton, D. W. 1960. Recent advances for the control of red-banded leaf rollers. Proc. North Cent. Br., E.S.A., 15: 54-55.

Hamilton, D. W. 1960. The codling moth and DDT. Proc. Ohio St. Hort. Soc. 113: 58-71.

Hamilton, D. W. 1961. Chemicals and procedures to effectively control oriental fruit moth, red-banded leaf roller and mites. Proc. Mich. Hort. Soc. Vol. 91, pp. 100-108.

Hamilton, D. W. 1961. Control of insects attacking apples. Proc. Ind. Hort. Soc. pp. 62-68.

Hamilton, D. W. 1961. Current investigations on the control of the codling moth and other apple insects. Proc. N. C. Branch, E.S.A., 16:75-77.

Hamilton, D. W. 1962. Preventing insect injury to peaches. Trans. of Ind. Hort. Soc. pp. 30-34.

Hoyt, S. C. and Harries, F. H. 1960. Laboratory and field studies on orchard mite resistance to Kelthane. Jour. Econ. Ent. 54(1): 12-16.

Kaloostian, G. H. 1961. Evaluation of adhesive for sticky board traps. Jour. Econ. Ent. 54(5): 1009-1011.

McGrew, J. R., Still, G. W. and Baker, Howard. 1961. Control of grape diseases and insects in eastern United States. FB 1893, U.S.D.A.

Osburn, M. R. and Tedders, W. L. 1961. Control of pecan leaf case-bearer. Proc. of the 54th Ann. Conv. of the Southwestern Pecan Growers Assoc.

Snapp, O. I. 1961. Treatment of peach nursery stock to prevent infestation by the peach tree borer. Jour. Econ. Ent. 54(2): 400.

Snapp, O. I., Savage, E. F., Hayden, R. A., Livingston, R. L., Jordan, D. R., and Farrar, L. L. 1961. Georgia peach spray schedule 1961. Circ. 375. Cooperative Extension Service, Univ. of Georgia, College of Agriculture, Athens, Georgia.

Snapp, O. I. 1962. Peach tree borer experiments in peach orchards. Jour. Econ. Ent. 55(3): 418-419.

Still, G. W. 1961. Traps for Rhagoletis species. Proc. N. C. Br., E.S.A., Vol. XVI.

Still, G. W. 1962. Cultural control of the grape berry moth. USDA, ARS, Agr. Info. Bull. 256.

Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock 1961 season. 1961 U.S.D.A. Agric. Handbook AH-120.

Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock 1962 season. 1962 U.S.D.A. Agric. Handbook AH-120.

Insecticide Residue Determinations

Bovard, K. P., Priode, B. M., Whitmore, G. E., and Ackerman, A. J. 1961. DDT residues in the internal fat of beef cattle fed contaminated apple pomace. Jour. Animal Science 20(4): 824-6.

Fahey, Jack E. 1959. Problems of pesticide residues on fruit. Proc. North Cent. Branch, E.S.A. Vol. 15, p. 71.

Fahey, J. E. and Still. G. W. 1961. Insecticide residue on grapes treated for control of insects. ARS-33-66.

Fahey, J. E., Hamilton, D. W., and Rusk, H. W. 1961. Current investigations of residues on tree fruits. Proc. N. C. Br., E.S.A. 16: 58-63.

Fahey, J. E., Rodriguez, J. G., Rusk, H. W. and Chaplin, C. E. 1962. Chemical evaluation of pesticide residues on strawberries. Jour. Econ. Ent. 55: 179-184.

Rodriguez, J. G., Chaplin, C. E. and Fahey, Jack E. 1962. Pesticide performance on strawberries. Jour. Econ. Ent. 55: 184-188.

Biological Control

Snapp, O. I. 1962. Peach tree borer experiments in peach orchards. Jour. Econ. Ent. 55(3): 418-419.

Insect Sterility, Attractants and Other New Approaches to Control

Cleveland, M. L. 1960. Soil injection as a means of applying systemic acaricides to fruit trees. Jour. Econ. Ent. 53(1): 144-146.

Evaluation of Equipment for Insect Detection and Control

Cleveland, M. L. 1960. Methods of determining orchard mite populations. Proc. North Cent. Br., E.S.A. 15: 50-51.
Hamilton, D. W. 1961. How the research entomologist can help with insect surveys, detection and loss estimates. Proc. N. C. Branch, E.S.A. 16: 126-128.
Kaloostian, G. H. 1961. Evaluation of adhesives for sticky board traps. Jour. Econ. Ent. 54(5): 1009-1011.
Still, G. W. 1961. Traps for Rhagoletis species. Proc. N. C. Branch, E.S.A. Vol. XVI.
Wilcox, J. and Howland, A. F. 1961. Control of aphids and spider mites on strawberries with dusts and low- and high-gallonage sprays. Jour. Econ. Ent. 54(2): 287-292.

Insect Vectors of Diseases

Jones, L. S. 1959. Control of vectors of plant viruses. Proc. IX Internat. Botanical Cong. Vol. IIA: 18.
Kaloostian, G. H. 1961. Evaluation of adhesives for sticky board traps. Jour. Econ. Ent. 54(5): 1009-1011.
Kaloostian, G. H., Pollard, H. N. and Turner, W. F. 1962. Leafhopper vectors of Pierce's disease virus in Georgia. Plant Disease Reporter 46(4): 292.
Pollard, H. N. and Kaloostian, G. H. 1961. Overwintering habits of Homalodisca coagulata (Say), the principal natural vector of phony peach disease virus. Jour. Econ. Ent.54(4): 810-811.
Pollard, H N. 1962. Sex determination of fifth-instar nymphs of leafhoppers (Cicadellidae, Proconiini). Jour. Econ. Ent. 55(1): 141.

AREA 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Efficient production of citrus and subtropical fruits depends upon the availability of effective measures for controlling the many insects and mites that attack these crops. Additional research is needed on biological control agents, including parasites, predators, and diseases, and on the integration of biological and chemical control measures. A search for safer, more effective, and more economical insecticides and for other types of insect control methods that will not result in harmful residues on the harvested crops or be detrimental to natural control agents is a continuing necessity. Research on the sterile male technique, attractants, and chemosterilants are among the new approaches that need to be investigated against a number of these pests. Protection against introduction into the United States of tropical fruit flies and other exotic pests requires the availability of effective, low-cost detection methods, quarantine treatments and eradication procedures that can be applied in emergency situations with minimum disturbance of trade or inconvenience to the public. There is constant need for research to improve present control methods and to develop the biological basis needed for their effective application.

USDA PROGRAM

The Department has a continuing program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic and applied research on a variety of problems in this area. Studies on basic biology, physiology and nutrition are carried on at Honolulu, Hilo, and Kahului, Hawaii; Riverside, Calif.; Orlando and Lake Alfred, Fla.; and Weslaco, Tex., in cooperation with the respective State Experiment Stations; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura; and at Brownsville, Tex. Research on insecticidal control is carried on at Honolulu, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Weslaco, Tex., in cooperation with the respective State Experiment Stations and at Mexico City, Mexico, in cooperation with the Defensa Agricola of the Mexican Secretaria de Agricultura. Determinations of residues resulting from use of insecticides, including fumigants, are made at Honolulu, Hawaii, and Mexico City, Mexico, and samples from Riverside, Calif., Orlando, Fla., Weslaco, Tex., and Hoboken, N. J., are sent to chemists of the Entomology Research Division,

cooperating States and industry for residue determinations. Biological control studies at Honolulu, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Weslaco, Tex., are cooperative with the Hawaii, California, Florida, and Texas Experiment Stations and at Mexico City, Mexico, with the Defensa Agricola of the Mexican Secretaria de Agricultura. Insect sterility, attractants, and other new approaches to control are the subject of research at Honolulu, Hawaii (including work on the islands of Guam, Rota, and the Bonin Islands), and at Orlando, Fla., and Mexico City, Mexico, with informal cooperation with local research stations. The evaluation of equipment for insect detection and control is carried on at Hilo and Honolulu, Hawaii, Orlando, Fla., and Mexico City, Mexico, also with informal cooperation with local research stations. Research on insect control treatments for commodities regulated by plant quarantines is the primary responsibility of the laboratory at Hoboken, N. J., in cooperation with the Plant Quarantine Division, aided by the laboratories at Honolulu, Hawaii, and Mexico City, Mexico, in cooperation with the Hawaiian Experiment Station and Defensa Agricola of the Mexican Secretaria de Agricultura, respectively. Research on varietal evaluation for insect resistance, carried on at Honolulu, Hawaii, and Mexico City, Mexico, is cooperative with the Hawaiian and California Experiment Stations and Plant Pest Control and Plant Quarantine Divisions. Research on insect vectors of diseases of citrus at Orlando, Fla., is cooperative with the Division of Plant Industry of the Florida Department of Agriculture and Crops Research Division.

In August 1961, a sublaboratory was established at Agana, Guam, as a base for continuing a practical test of the male sterilization technique for the control of subtropical fruit flies; and in April 1962, a laboratory was established at Weslaco, Tex., in cooperation with the Texas Experiment Station, for research on the brown soft scale on citrus. Facilities for carrying on research have been greatly improved at Orlando, Fla., and in California. New quarters were provided at Riverside, Calif., in January 1961 and personnel transferred there from the station at Whittier, Calif., which was closed at that time.

Additional research (4 professional man-years) is in progress under a grant of P. L. 480 funds to the Plant Protection Department of the Arab Republic, Dokki, Egypt, for studies of induced sterility in males of the Mediterranean fruit fly, Ceratitis capitata, as a means of controlling and eradicating this pest. In addition, a portion of a grant of P. L. 480 funds (10 professional man-years) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan, is applicable to insects

affecting citrus fruits and to tropical and subtropical fruit fly problems in the United States.

The Federal scientific effort devoted to research in this area totals 29.9 professional man-years. Of this number, 5.6 is devoted to basic biology, physiology and nutrition; 3.4 to insecticidal control; 2.0 to insecticide residue determinations; 2.4 to biological control; 8.2 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.6 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 18.3 professional man-years divided among subheadings as follows: Basic biology, physiology, and nutrition 2.9; insecticidal and cultural control 7.8; insecticide residues 2.4; biological control 2.9; insect sterility, attractants, and other new approaches to control 0.2; evaluation of equipment for insect detection and control 1.0; insect control treatments for commodities regulated by Plant Quarantine 0.4; varietal evaluation for insect resistance 0.3; and insect vectors of diseases 0.4. Florida, Texas, and California are conducting research on basic biology, physiology, and nutrition, insecticidal and cultural control, and biological control. Florida and California conduct the bulk of research on insecticide residues, evaluation of equipment for insect detection and control, insect control treatments for commodities regulated by plant quarantines and on insect vectors of diseases. Research on insect sterility, attractants, and other new approaches to control and on varietal evaluation of insect resistance is carried on by California.

Industry and other organizations, including grove owners, conduct research on insect problems on citrus and other subtropical crops. A number of chemical companies develop and supply insect control materials for evaluation by official agencies and some conduct research on insect control directly with growers. Grove owners furnish their plantings and facilities for the conduct of research for insect control. Packing houses furnish fruit and facilities for the development of commodity treatments to permit movement of regulated products under plant quarantines. Estimated annual expenditures by industry are equivalent to approximately 3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Citrus Insects and Mites. Effective techniques for rearing rust mites are needed to provide colonies for evaluating sterilants, antimetabolites and other biologically active agents. In Florida rearing has been most successful on Murcott honey orange seedlings in air-conditioned greenhouses. High populations were maintained for 9 months on the same group of seedlings without serious damage to plants. Calamondin and Key lime seedlings were not suitable hosts for the rust mite but Temple orange seedlings showed possibilities. Green lemons partially immersed in water were excellent hosts at Riverside, Calif. Excised leaves of lemon, grapefruit and orange on a moist substrate were less satisfactory. Recently, mites have been reared for 6 weeks on green lemons at Orlando, Fla. Calamondin fruit appeared to be an even better host. Exploratory work on the possibility of propagating citrus red mite on an artificial medium has shown that mites will feed through a collodion or some plastic membrane on aqueous solutions of sucrose or agar media containing sucrose. Rearing of the citrus rust mite was not successful in constant temperature rooms held at 80° F. and 70-95% or 30-35% R.H., at Orlando. At Riverside, 80° F. and 70-80% R.H., in a room with a carbon filter was very favorable for rust mite development; continuous low humidity was unfavorable. A fungus disease, Hirsutella, may limit reproduction and development of this mite at high humidity in Florida.

Populations of a pink rust mite that developed in citrus rust mite colonies in the greenhouse at Orlando, Fla., were identified as Aculus pelekassi (Keifer), a species described from citrus in Greece and not previously recorded in the United States. This mite has been found at a few widely scattered locations in Florida, but its economic importance remains to be determined. An albino strain of citrus red mite has been isolated and is being maintained for experimental purposes at Riverside, Calif. Albinism is due to a single recessive gene.

2. Subtropical Fruit Flies. Oriental fruit fly and melon fly abundance remained at high levels throughout the Hawaiian Islands. Approximately 7 million male oriental fruit flies - 490 per trap day - were caught in 39 methyl eugenol traps on four islands during a 12-month period ending March 31, 1962. Nearly ½ million melon fly males - 19 per trap day - and 33,000 Medflies were taken in 65 traps.

Fruit fly hosts producing 10 larvae per pound on one or more islands included guava, false kamani, mango, loquat, peach, rose apple, calamondin, plum, coffee, avocado, mock orange, gourka, apricot, black walnut, English walnut, Surinam cherry, Jerusalem cherry, Barbados cherry, a Solanum sp., white sapote, and Brazilian plum. Mock orange produced 1,540 larvae per pound. Most of the larvae reared from fruits at low elevations were oriental fruit flies. The Medfly was the dominant species in deciduous fruits growing at high, cool locations, and in coffee. Momordica sp. and tomato had the heaviest melon fly infestations.

Breadfruit, a minor host of the oriental fruit fly in Hawaii, where wild preferred hosts are abundant, produced large numbers of these flies on Rota. The oriental fruit fly attacked Pandanus on Rota but not in Hawaii.

Following the interception of a melon fly larva by the Plant Quarantine Division in the blossoms of Sesbania grandiflora, melon flies were found to be strongly attracted to buds and flowers of the plant in Honolulu, Hawaii. Melon flies and oriental fruit flies were reared from field collections. Buds of both pink and white varieties proved to be good hosts in induced oviposition tests. Medfly pupae were also obtained but no emergence occurred. In other induced oviposition tests buds and flowers of red jade, Mucuna novoguinensis, and the sausage tree, Kigelia pinnata, supported development of melon flies. Oriental fruit fly pupae were recovered from the blue-green jade, Strongylodon macrobotry; and both oriental fruit fly and Mediterranean fruit fly pupae were obtained from collections from a sausage tree, but no emergence resulted.

Other new fruit fly infestation records for Hawaii included "Akee" and Blighia sapida, hosts of both the Medfly and oriental fruit fly; Rhudia edulis, host of the oriental fruit fly; and tree tomato, Cyphonandra betacea, host of the Medfly. Japoticaba, Myriciadia cauliflora, produced both oriental fruit flies and melon flies and Java plum, Eugenia cumini, oriental fruit flies in cage tests. Neither produced melon flies. Limeberry, Triphasia trifoliae, an important host of the oriental fruit fly in the Mariana Islands, was highly susceptible to both the oriental fruit fly and the Medfly in Hawaii laboratory tests. Velvet apple, Diospyros discolor, produced melon flies. Cucumbers, Cucumis sativus, exposed simultaneously to melon fly and oriental fruit fly produced both species. Proof is still lacking that prior infestation by the melon fly is a prerequisite for successful establishment of oriental fruit fly infestation in cucumber.

California lemons developed oriental fruit fly infestation when exposed to 25 or more females for 24 hours or longer. Holding the infested lemons for 30 days at temperatures of 56-58° F. and 60-65% R. H. reduced the yield of fruit flies from an average of 0.54 to 0.04 larvae per fruit. All but one of the infested fruits developed green mold and broke down rapidly under the cool storage conditions. These would have been eliminated during normal grading for market. Breadfruit subjected to 2, 4, 8, 16, or 32 female oriental fruit flies for several days, produced 0.5, 8.5, 13.5, 20.1, and 15.7 progeny per female in very uniform fruits. In breadfruit varying in degree of ripeness results were variable. As many as 137 larvae were found to have pupated and emerged inside single fruits from which they could not escape as larvae.

A search for hosts of Anastrepha spatulata, a fruit fly which has been trapped in considerable numbers in Texas in recent years, and for hosts of a closely related species was continued without success, by the Mexican station. Practically all wild fruits available to these species appear to have been investigated.

The annual survey of yellow chapote at 7 ecological stations in northeastern Mexico made in early summer of 1961, disclosed no fruit or very sparse fruiting with light infestation of the Mexican fruit fly. The very low catch of 14 flies in Texas citrus before a severe freeze in January 1962, provides further indication that populations of flies appearing there during the harvest season are probably dependent upon breeding in yellow chapote in Mexico.

Under cage conditions in Hawaii sexual maturity tests with wild and laboratory strains of oriental fruit flies and melon flies indicate that the latter reach sexual maturity at a much younger age. The pairing of wild and laboratory-reared melon flies resulted in a decrease in mating frequency as compared with that of laboratory-reared flies, due in part, it is believed, to delayed sexual maturity of the wild flies.

Additional sex ratio tests confirmed previous results obtained in Hawaii with the oriental fruit fly and the Mediterranean fruit fly, which indicated that reduced mating resulted in a reduction in the number of eggs deposited as well as a reduction in the percent of eggs that hatched. Melon flies produced 90% fewer eggs when there were no males. The percent hatch and total number of eggs deposited by 50 females did not differ significantly when 2, 10, or 50 males were present.

Recent tests in Hawaii with the laboratory, genetically-marked white strain of oriental fruit flies indicate that this strain is compatible with wild oriental fruit flies. The wild strain flies

were far less productive and reach sexual maturity at a later age but the recovery of fertile eggs from reciprocal crosses proved that there was inter-strain mating. A virtually pure white-marked strain of the oriental fruit fly was developed for use in a radiation sterilization experiment on Rota. In genetic studies the white marking behaved as a recessive to yellow. The white flies provide means of quick identification after release and a basis for estimating ratios of sterile to wild flies.

Female oriental fruit flies copulate several times and individual males have fertilized as many as 26 different females in a lifetime. Crosses between white and yellow-marked flies with opportunities for second matings indicated definitely that little additional sperm is deposited in the spermatheca by second matings. Successful insemination of normal females mated previously with unirradiated males may not exceed more than 1 or 2 per female during the first month of life. The testes of normal males remained full of sperm throughout life. The sperm content of irradiated males decreased to a very low level within 30 days. Females that mated first with sterile males were inseminated when mated again with normal males. Females mated first with normal males were less likely to be affected by subsequent matings with sterile males. Size of fly was also not a factor in mating effectiveness.

In the Western Pacific, studies were made of the compatibility of Rota wild flies and a laboratory strain of sterilized flies. The suppressive effect of overflooding in cages at a ratio of 10 sterile flies to 1 normal fly was better than the expected theoretical effect, suggesting that the earlier sexual maturity and greater vigor of the laboratory strain of flies may be more than compensating for the adverse effect, if any, of irradiation on mating and compatibility under cage conditions. Longevity tests in field cages at an altitude of 4700 feet indicated that Medflies reared from Jerusalem cherries will live longer than Medflies reared from peaches or those produced on artificial media in the laboratory.

Improvements were made in fruit fly rearing techniques in Hawaii. Comparisons of the low-cost Type M hydrolyzed protein ($1.05 per pound) and the high-cost standard MRT ($7.00 per pound) in the fruit fly rearing medium gave variable results. Differences in humidity control, lighting, etc., may be factors but the diet has been modified to utilize a combination of Type M and MRT protein hydrolysates in a 3:1 ratio with both greater egg deposition and higher percent hatch than obtained with either material alone. Granular dehydrated carrots in the rearing medium were slightly inferior to powdered carrots.

Substitution of granulated vermiculite for sand as a pupation medium permits use of economical, plastic, stackable containers and has the advantages of low weight, less critical moisture requirements, and less tendency for the larvae to escape. Use of vermiculite and cheap soy and yeast hydrolysates will reduce production costs still further. Guava juice diluted with water (2:1) was as effective as undiluted guava juice for wetting the insides of the 1 quart plastic, cylindrical oviposition devices. Four to six of these, each with 300 pin holes, were as effective in cages stocked with 25,000 flies as larger numbers of the cylinders or the use of more holes. In a two-year period production costs for the oriental fruit fly and melon fly have been reduced from $235 to $100 per million.

Improvements were also made in rearing methods for the Mexican fruit fly in Mexico. The 15 million larvae produced in the laboratory during the year were largely reared on fresh carrot fortified with brewers' yeast. Dehydrated carrot was adopted as a rearing medium only recently after it was found that addition of yeast hydrolysate results in recovery of larvae equivalent to that obtained with fresh carrot. Increasing males to females in ratios up to 4:1 in breeding cages failed to improve fertility. Cholesterol at 1% added to the fly diet increased oviposition 25% with high fertility and normal adult mortality resulting.

3. Miscellaneous Subtropical Fruit Insects. Trioza anceps, the leaf gall psyllid of avocado, is a serious pest in many parts of Mexico and may become a problem if it should become established in the United States. Adult psyllids were caught in Morelos, Mexico, in all months from December 1959 to June 1961 except September 1960. The highest catches were in June 1960; the next highest in December 1959 and 1960. It is evident that this psyllid is active throughout most of the year.

Continued studies with the mango seed weevil in Hawaii confirmed previous observations that at least 7 to 8 months are required for adults to become sexually mature. This is roughly the period between normal mango fruiting periods. A few females have been under observation for 17 months without laying eggs. Dissection of individual females and males from this lot showed that the reproductive organs were poorly developed.

B. Insecticidal Control

1. Citrus Insects and Mites. In Florida the most serious pest of citrus is the citrus rust mite. Citrus red mites and Texas citrus mites are also important. In 1961 there were numerous reports of

poor control of rust mites with zineb, one of the most effective of recent materials used by growers. In two groves under observation, control was not satisfactory; in two Valencia blocks postbloom zineb followed by a summer oil-zineb spray gave adequate control. Zineb (75 WP), 1 pound per 100 gallons applied in August 1961 gave satisfactory control of this mite for over 3 months on grapefruit and was superior to Imidan (4 EV) at 1 pint or ½ pint, Sevin (50 WP) 2 pounds and dimethoate (50 EC) 1 pint Hooker Compounds 720 and 16 gave poor control and Niagara 9044 was followed by an increase in rust mites.

Eradex was effective against all three species of mites in Florida but this material was dropped from further development because it produces allergy in workers on repeated exposures. Delnav gave better control of citrus red mites and Texas citrus mites than Trithion or ethion.

Because of the development of mite resistance to new acaricides, there is no generally satisfactory control for the citrus red mite in California where it is now the most serious pest of citrus. The rate of loss of resistance to demeton and ovex in strains collected in 1958 and maintained in the Riverside, Calif., laboratory since then without treatment appeared to be leveling off at a value of 35 to 50 times the tolerance of the non-resistant strain. An accidental exposure to Trithion-treated fruit increased the resistance level of demeton-resistant citrus red mite from 35 to 117 times. Eleven months later the resistance decreased to 11 times. The ovex-resistant strain has had no previous exposure to organic phosphorus compounds. Little or no change occurred in the non-resistant strain. These studies indicate that a significant amount of field-induced resistance may be retained after many generations without exposure to the chemicals.

Chemicals tested as miticides in Florida were also evaluated for toxicity to scale insects. Dimethoate (50 EC) at 1 pint per 100 gallons continued to be the most effective compound. Imidan (4 EV) at 1 or ½ pint was the only other new material with promise. A new formulation of dimethoate EC caused some plant injury when applied with hand sprayers but not when applied with continuous agitation.

In California, growers now have a choice of materials for use in an annual 2-spray program for California red scale control. Dimethoate and parathion alone or in combination at reduced strengths gave excellent control in several comparative tests. Kerosene plus parathion and oil plus malathion were also effective. Shell compound SD 3562 was the most promising of the new materials

screened against California red scale. This material in field sprays did not injure Navel and Valencia oranges. Other compounds screened in the laboratory that compared favorably with parathion were Stauffer compound R 3413, American Cyanamid 43064 and Bayer 45432. California red scales reared from survivors of parathion sprays in 15 generations were only slightly more tolerant of parathion than the untreated strain. Since the difference was about the same as that found after 4 and 8 parathion treatments, no specific resistance was indicated.

Experiments were conducted to obtain further data on possible damage to citrus from application of fruit fly bait sprays following or in combination with copper. There was no injury to fruit when copper, oil, malathion, or Staley's insecticide bait No. 7 (SIB-7) were used separately or in various combinations. SIB-7 applied either alone or in combination with the other materials caused an increase in drop of older leaves.

After a 10-year period in which citrus thrips seldom reached economic levels in southern California, populations increased in the last 2 years to heavy infestations in 1961. Summer infestations were especially difficult to control. The earlier decline in thrips infestations coincided with the general use of parathion for scale control.

2. Subtropical Fruit Flies. In a search in Hawaii for improved bait spray formulations, use of a toxicant in liquid SIB-7 protein hydrolysate without further dilution with water gave promising results. This type of bait spray (with Baytex or malathion technical as the toxicant) may provide means of greatly reducing aerial application costs by decreasing amounts of liquid required per acre. A new 50% wettable powder malathion formulation gave better results than the standard 25% material in preliminary tests, suggesting another possibility for using less water per acre. Cue-lure can be applied directly to foliage with good results in killing male melon flies provided it contains a suitable toxicant. Baytex, 2% was four times as effective as a toxicant in combination with cue-lure as DDVP, 2%, during a 2-week period; kill with Stauffer R-1504, 2%, was 50% greater than with Baytex. Preliminary tests of acid hydrolysate of corn protein in liquid form used in bait sprays with emulsifiable malathion showed that the best formulations were only moderately less efficient than the present standard formulation. Such formulations may have some advantage when aerial applications are made.

In Mexico City, Mexico, screening tests of 33 insecticides in a continuing study to find an insecticide for the Mexican fruit fly with residual toxicity greater than that of malathion and a

comparable low hazard index revealed four that warrant further study in the field. Evaluation of Baytex, a material which has shown unusual promise as a Mexican fruit fly insecticide, has been retarded because it has not been registered for application to edible crops.

The effectiveness of soil applications of emulsifiable, wettable powder and granular formulations of endrin and dieldrin against Mexican fruit fly larvae and pupae in the soil is being studied in Mexico City, Mexico. After two years endrin was superior to dieldrin. Dieldrin was as effective as endrin for 546 days with the exception of the granular formulation. Beginning with the larval introduction made 371 days after application, granular endrin was superior to all other formulations. A waterproofed heptachlor prepared by the Plant Pest Control Division was the most effective of five formulations of this insecticide when tested 218 days after application, slightly more effective after 381 days and about equal to the other after 586 days. At this time both 5 and 10-pound dosages of all formulations gave 50% or less mortality of introduced larvae.

C. Insecticide Residue Determinations

1. Subtropical Fruit Flies. At Mexico City, Mexico, in-package fumigation of grapefruit with ethylene dibromide at 50°, 74°, and 90° F., with dosages of 0.36 ml. and 0.48 ml. per carton for 24 hours, resulted in EDB residues (determined as bromine) 24 hours after treatment ranging from 2 p.p.m. to 8.8 p.p.m. Residues were greatest after treatment at 50° and least when the temperature was 90°.

2. Miscellaneous Crops. Residual bromide resulting from fumigations of asparagus in Hawaii with dosages of 3 to 6 pounds of methyl bromide per 1000 cubic feet for 2 hours at 59° or 70° F. after 3 days storage at 45° F. were almost entirely inorganic bromides and ranged from 48 p.p.m. to 102 p.p.m. Results of cooperative tests at Hoboken, N. J., with Dow Chemical Company indicated that the inorganic bromide residues in Golden Delicious or Lady apples from either methyl bromide alone or in combination with ethylene dibromide at either warm or cool temperatures come very close to or were under the present 5 p.p.m. Food and Drug tolerance. These results differed from those obtained in 1959 when residues were as high as 10 to 20 p.p.m. after warm fumigation and zero after cool fumigation. After consideration of residue analyses in cabbage fumigated with methyl bromide under different conditions, the Food and Drug Administration recently approved a tolerance of 50 p.p.m. inorganic bromide for cabbage. Similar studies are underway with Guar (Cyamopsis) seed.

3. Analytical Equipment.--In further studies at Hoboken, N. J., with the Fumiscope and other thermal conductivity gas analysis equipment used in determining methyl bromide gas concentrations inside fumigation chambers, generally satisfactory readings were obtained under a wide range of temperature conditions. The Fumiscope is small and convenient and appears to be better insulated from outside conditions than other equipment, as well as sufficiently accurate for field use. Study is being continued as to the most desirable procedure for use under high humidity conditions. In further studies with thermal conductivity (T/C) apparatus for checking fumigation gas concentrations, carbon tetrachloride was not promising for use to calibrate T/C sets. Sulfuryl fluoride (Vikane) gave a fast, steady signal and was more promising than carbon tetrachloride. Tests with a special "sachet" for ethylene oxide confirmed the usefulness of the T/C set for checking carboxide fumigations. The T/C equipment has been so sensitive to carboxide that it now appears to be the most useful instrument available for checking carboxide leakage. In further tests this equipment did not appear promising for analysis of ethylene dibromide.

D. Biological Control

1. Citrus Insects and Mites. Laboratory and grove studies to determine the status and value of parasites, predators, and diseases that attack citrus insects and mites, additional natural enemies that may be needed, the effects of pesticides and other grove practices on biological control agents and development of selective treatments and procedures for use in integrated control programs, are long-range objectives of the studies being conducted at Lake Alfred in cooperation with the Florida Citrus Experiment Station and at Orlando, Fla. Sprays containing DDT, copper, captan, nutritional zinc and manganese, Chlorobenzilate, Kelthane, Trithion, and Tedion varied widely in their effects on beneficial species of mites and insects. DDT and Kelthane were most destructive while captan and the nutritional compounds were least harmful to the majority of predators. Fall infestations of Florida red scale were heaviest in DDT and nutritional plots following reduced parasitism by Pseudhomalopoda prima. Heavier chaff scale infestations in DDT, nutritional, and Kelthane plots were correlated with reduced parasitism. Heavier spider mite infestations in DDT and copper plots also suggested an adverse effect of the sprays on natural enemies. Populations of purple scale and its parasite Aphytis lepidosaphes were relatively uniform in all plots. Eradex was toxic to predaceous mites as well as to plant feeding species. It practically eliminated Agistemus mites (predators) and Tydeus mites (fungus feeders) within four weeks after application. Trithion, ethion, and Delnav concentra-

tions at half the usually recommended dosages were much less injurious to beneficial species than Eradex, and Zineb was considerably less so.

A parasite of the snow scale was again recovered at the Orlando station. This species, not abundant in recent years, has been identified as belonging to the Aphytis mytilaspidis group or as being indistinguishable from A. lingnanensis.

Aphytis holoxanthus, a parasite of Florida red scale introduced in the fall of 1960, spread rapidly and was found in practically all of the citrus-producing areas of the State during 1961. Parasitism rates averaged 29% in survey groves in the spring of 1962, with a maximum in one grove of 84%. Parasitism averaged 7% in the spring of 1961.

Periodic scale and scale parasite surveys in 27 Florida groves - 9 untreated, 9 with sulfur in the program, and 9 without sulfur - revealed that scales are most abundant in groves receiving sulfur, and intermediate in abundance in untreated groves. Parasitism of purple and Florida red scales was adversely affected by sulfur but scale populations in all groves were below economic levels. In the third year of comparison of zineb, oil + zineb and sulfur spray programs following postbloom copper and arsenic on grapefruit, scale insects were lowest in the oil-zineb plot and highest in the sulfur. Brevipalpus mites were most numerous in the zineb plot. The predaceous mites, Amblyseius (Typhlodromus) peregrinus and A. quadripilis, again were most abundant in the sulfur plots. Agistemus fleschneri was most numerous in the oil-zineb; Aleurodothrips fasciapennis in the sulfur plot. Sulfur has no effect on this thrips. In two groves in which Manatee or citrus tree snails were excluded from some trees by tanglefoot-copper barriers, no difference in numbers of pest and beneficial species on banded and unbanded trees was evident the second year of the experiment.

Basic research on a new virus disease of the citrus red mite in California, and on possible practical means of storing and utilizing this pathogen have continued to receive major attention by the Riverside station. Two convenient methods of storage of inoculum for six months to a year without loss of virulence were perfected. One method uses storage of the dry bodies of diseased mites at -10° F.; the other, storage of suspension of macerated diseased mites in 3 M glycerine also at -10° F.; the latter showed no loss of virulence after 75 weeks. Activity was lost more quickly at 45° F. Freeze dried preparations also had good keeping qualities, remaining infective after 92 weeks of storage at -10° F.

Sprays of the aqueous suspension of this virus disease of mites caused infection in 100% of the tests where the interval between spraying the host fruit and infesting with mites was 2 hours or less; in 14% with a 24-hour interval; and in none of the tests after 48 hours. The incidence of infection of the citrus red mite by the virus increased with greater population density. Some additives did not prolong the life of the residue but gelatin may have had some effect. The longer life of the natural residues on lemons resulting from the presence of diseased mites has not yet been explained. Fecal deposits removed from such lemons were not infective.

Two predaceous mites, Typhlodromus occidentalis and Phytoseiulus macropilus, were not affected by feeding on diseased red mites.

Earlier reports that a single mite infected with this virus is able to initiate infection in a healthy colony were confirmed. Single inoculated mites introduced into healthy colonies of several hundred mites per lemon induced infection comparable to that produced by spraying them with aqueous suspensions of the pathogen. This virus disease of the citrus red mite has persisted in field plots at Oxnard and Corona, Calif., that were experimentally infected in the fall of 1960. In the Oxnard grove which was heavily infested by mites at the time of treatment, several substandard applications of an acaricide were needed to suppress mite populations. In the Corona plots, initially very lightly infested, populations have not built up even though there has been no evidence of high incidence of disease.

Birefringent crystals were found in diseased cultures of the mites but not in healthy colonies. The crystals first appeared 7 to 8 days after inoculation with the virus; they occurred in 84% of the paralyzed and recently dead females and in 59% of the still active mites. The crystals will probably have diagnostic value in laboratory and field studies.

Attempts are underway to establish in Florida the virus disease of citrus red mites which is present in California and also the mite predator, Amblydromella richeri, which is being reared by the Department of Biological Control, University of California, at Riverside.

2. Subtropical Fruit Flies. Infestation data from more than 635,000 fruits collected on Hawaii and Maui since 1945 show that fruit fly infestations in preferred hosts have not changed significantly since 1950. The failure of the present biological

control complex to reduce infestations to levels acceptable in commercial fruit production suggests the desirability of further work on biological control. Parasitization during the year in the Hawaiian Islands exceeded 70% only in fruit flies infesting rose apple, mountain apple, coffee, and Surinam cherry. The average rate in guava was 50%. It was again low in the melon fly and in the Medfly except on these insects in coffee. Parasitization by Opius oophilus was substantially higher in oriental fruit fly pupae than in Medfly pupae when both of these species occurred together in such hosts as loquat, calamondin, cotton, and plum. This parasite again appeared to be much less important as a parasite of the Medfly than of the oriental fruit fly, and might not be able to survive in the complete absence of the latter. No parasites were reared from fruit flies from fruits collected in the Bonin Islands. Although parasite species present in Hawaii, such as O. longicaudatus and O. oophilus, have been reared from fruit collected on Rota, the parasitization rate has rarely exceeded 5%.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Citrus Insects and Mites. Because of resistance to the best of the new acaricides there is no generally satisfactory control available for the citrus red mite in California at the present time, a situation suggesting the need to explore other possible means of control. In exploratory studies at Riverside. with potential chemical sterilants, ENT 24,915, 26,315, and 26,316 reduced productivity of the treated females and viability of eggs and larvae of the second generation; only 1 female among the offspring matured, indicating almost complete sterilization. Fertilized eggs normally produce only females. Male offspring of citrus red mites treated with the chemical sterilant, tepa, were fertile. Normal virgin females mated with such males produced as many females as the checks. These compounds are too toxic for field trials but the results demonstrate effects that may be obtained by contaminating mite environments with them.

The ether extract of carbon which had been used for purification of air in an air-conditioned rearing room was toxic to red mites; the water extract was non-toxic. The ether extract of unused carbon was also nontoxic.

2. Subtropical Fruit Flies. Increased attention was given to the screening and development of information of chemosterilants during the last 15 months in Hawaii. Of about 250 compounds tested on the oriental fruit fly, tepa, tretamine, ENT-22690

and ENT-32838 showed promise as both male and female chemosterilants, ENT-22878, 4878, 23562, and 23569 showed possible value as male sterilants, and ENT-15239, 50170, and D-57 showed value as female sterilants. In tests with a wide range of dosages most materials were more effective on the oriental fruit fly and the melon fly than on the Mediterranean fruit fly. Effective sterilization by tepa, apholate, and tretamine was obtained at dosages of .0004 to .0125% in drinking water and when adults were anesthetized and dipped for 15 seconds in .016 to .25% solutions. When apholate was included in the carrot-rearing media at 2%, no sterilization resulted and mortality of larvae and pupae was high. High mortality also resulted at dosages as low as .5% when mature larvae were dipped in solutions for 15 seconds. Dosages in dips or drinking water that gave sterilization were generally non-injurious except in some melon fly tests. Pupal dips at concentrations up to .5% had no significant effect on eggs or fertility of the melon fly.

More than 1600 possible fruit fly development or reproduction inhibitors have been screened in Mexico City since 1959 at low concentration in fruit fly diets or in drinking water. Thirty-two materials proved to be highly effective, affecting testes, ovaries or gonads of both sexes. Flies fed biotin or vitamin H produced no eggs and male mortality was abnormal. Adult flies were permanently sterilized when immersed for 5 seconds in a 0.2% aqueous solution of tepa and also when the material was applied in an atomized spray. Tepa in the larval rearing medium was ineffective. Immersion of puparia in a 5% tepa solution followed by drying was ineffective but when the puparia were immersed for one minute and then held without drying, complete sterility resulted. Pre-emergence and post-emergence mortalities of flies from immersed puparia were normal. When sterile and normal flies were crossed, the normal females mated with sterile males laid 6,915 eggs with less than 1% hatch. There was no larval development. Treated females mated with normal males laid no eggs. Sterile females mated with sterile males laid 4 eggs but none of these hatched. In a series of observations on mating behavior in which aggressiveness of males from puparia treated with 5% tepa solution was compared with males from untreated puparia, ratios of sterile males mating to untreated males mating were 1.14:1 at 12 - 29 days of age and 1.16:1 at 33 - 50 days. When puparia treated with 5% tepa solution were released in a semi-isolated 10-acre mango grove in Mexico bearing a light, though heavily infested off-season crop of fruit and a heavy set of immature fruit, infestation was greatly reduced and a major part of the regular season crop was protected and harvested, whereas virtually all fruit in check groves was lost from infestation.

After treatment of 12-day old pupae of the Mexican fruit fly with 5,000 r of radiation from cobalt 60, emerging adults were sterile. In a former study treatment of puparia was more effective at 90 r per minute than at 10 r at a marginal sterilization dosage of 2,000 r. In recent tests after sterilization of puparia at rates of 2,695 r and 42.8 r per minute there was no apparent effect of the higher dosage rate on emergence or longevity of adults. Both sexes were sterilized when a 5000 r dosage was fractioned, with application of 2,500 r being followed by the same amount after a 24-hour interval. When 12-day-old puparia were administered dosages up to 7,000 r in an N_2 atmosphere, there was little sterilization effect; when puparia were irradiated in an O_2 atmosphere at 7,000 r some fertile eggs were obtained from emerged adults.

The release of sterile flies was continued in 1961 at the same two locations in Mexico where sterile flies were released in 1960. At Santa Rosa, where 838,000 sterile flies were released in a semi-isolated hacienda with about one acre of citrus (mostly grapefruit) and one square mile of other hosts, only 5.5 larvae per pound were recovered from 2 tons of fruit despite an infestation potentially double that of the preceding year. In the previous season, after release of 1,172,000 sterile flies, infestations averaged 6.9 per pound. At San Carlos similar results were obtained in 1960 and 1961. Releases made at San Carlos in February 1962 and continued until June 6 gave a mean 8:1 ratio of non-gravid to gravid flies but the native fly population was so high that there was little suppression of infestation.

In a male annihilation test in the Bonin Islands (approximately 27 square miles of land mass) initiated late in 1960 and continued until the present time, Celotex wafers ($2\frac{1}{4}$" x $2\frac{1}{4}$" x 5/16"), saturated with methyl eugenol containing 3% by volume of dibrom, which attract and kill male oriental fruit flies, have been distributed by air at the rate of 70 per square mile. Intervals between applications ranged from 10 to 67 days. Permanent poisoned-bait stations serviced from the ground were maintained in an inhabited area. Trap catches averaged 47,400 oriental fruit fly males per 1000 trap days in March, 1958, and 13,700 in January 1960 before treatments began. Catches were only 170 flies per 1000 trap days in March 1961 and 194 in March, 114 in April, 204 in May, and 81 in June 1962. The lowest density during the experiment of 28 flies per 1000 trap days was attained in September 1961. For the first time in several years, no infestations appeared in recent harvested tomatoes in the Islands but after sampling was discontinued there was a rather heavy attack in scattered tomatoes left in the field at the end of the crop season. Increases in flies during periods when unusually

long intervals between applications were necessary, reflected the high reproductive potential of the oriental fruit fly and need for continued regular suppression of males for several weeks beyond the last fly catches if this method is to achieve eradication.

Field tests of the sterile-male release method were started in late 1960 on Rota, a small island located 40 miles northeast of Guam. The oriental fruit fly and the melon fly were released until June 1961, when work with the melon fly was discontinued because of inability to give attention to both species simultaneously. In the continuing studies with the oriental fruit fly a wealth of information with much basic significance has been accumulated. Thus far, however, sustained overflooding of the wild fly population with sterile flies at the 10:1 ratio or higher, estimated to be required for effectiveness, has not been achieved. Late in November 1961 the release rate was increased to almost 10 million pupae per week, with ground emergences supplementing aerial drops, and overflooding was attained in all areas with a ratio as high as 5 sterile flies to 1 wild fly in some areas and an average of at least 4 to 1 on the southwest half of the island where preferred hosts are most abundant. An estimated one-fourth billion sterile oriental fruit flies were released during a recent 12-month period. The mid-February 1962 release rate was 20 times as high as the estimated weekly birth rate. Declining wildfly birth rates and seasonably low populations are the basis for hope that effective overflooding may yet be obtained.

Fruit flies from ground releases distributed themselves satisfactorily throughout most areas, and their survival and longevity may be better than that of flies released from aircraft. Some of the flies dropped from airplanes too close to the shoreline of the small island drifted out to sea, particularly when boxes broke open at plane height. Chutes designed to deliver boxes into the airstream with less shock were tested but in the best performance from 18 to 20% were ripped open by the air blast. Throwing the boxes out by hand at a higher level through the open door of the airplane eliminated most breakup and this method is now being used.

The southwestern end of Rota has consistently produced the most flies, partly because of immigration from the upwind (NE) end, but mainly because of the greater abundance of hosts there throughout the season. The weekly mean percentages of sterile flies in the southwest (downwind) areas was 93 in early March 1962, 67 in early April, and 89 in early May. Thereafter, by the end of June, there was a marked decline to 35%, because of increases in the number of

wild flies. In early March 1962, the wild fly per-trap-day catch in the northeastern upwind portion of the island increased from 75% sterile in early March to 98.5% by early June and wild fly catches were only 0.2 per trap day. By the end of June there was still a 12:1 sterile-wild fly ratio in this part of the island. Migration from high-producing areas has since resulted in an increase in wild flies.

Supplies and equipment are being assembled for resumption of sterile melon fly tests on Rota. This species reproduces largely in cultivated farm plots. Bait sprays are being applied to the producing areas (50 to 100 acres) to reduce the numbers of flies to a point where they may be eliminated with releases of sterile flies at a minimum cost.

Attempts to segregate and produce a genetically-marked melon fly strain have failed. Rare specimens of wild flies with very faint wing markings or with white instead of yellow markings have been found in the field on Rota. Flies so marked could be used as indicators of sterility if a laboratory strain with these characteristics could be produced. Attempts to inter-breed the marked wild flies to produce a pure strain have not been successful in tests now in the third generation. All production, except 3 individuals, reverted to the normal markings.

In Hawaii 220 fermentation products furnished by the Northern Utilization and Development Division were tested against standard yeast hydrolysate type M liquid lure in laboratory olfactometer tests. Forty-three were attractive to one species of fruit fly only and 45 were attractive to two species. Fifteen were equal or superior to the standard in attractiveness to all three fruit flies. Field tests with the last, and materials that were especially attractive to the melon fly or the Medfly, are desirable. Screening of fermentation products was discontinued in December since none had approached the outstanding effectiveness of the best synthetic male attractants. Two hundred fifteen candidate chemical lures, supplied largely by the Pesticide Chemicals Research Branch, were also tested. Only two were highly attractive to the male Medfly in trap tests but in wick tests these were much less attractive than standard trimedlure. None of the others were attractive enough to warrant field evaluation. Promising enzymatic protein hydrolysates of soybean and cottonseed were attractive to all three species of fruit flies in Hawaii, particularly female melon flies. The addition of borax, a development of the Mexico laboratory, resulted in increased catches of some flies but not others when used with either one or the other of these hydrolysates.

The long-lasting quality of cue-lure as a melon fly male attractant was demonstrated in a field test in which cotton wicks, originally treated 6 months previously with 2 ml. of lure containing 1% dibrom, were no less effective in attracting melon flies than fresh-treated wicks. A comparison of crude and distilled samples of cue-lure during a half-year period showed that purified materials were only 15% better than the crude material. Cue-lure in combination with 1% dibrom did not crystallize in Hawaii but when used on Rota at higher temperatures, crystallization occurred. With periodic addition of more lure the wicks accumulated up to 1.5 times the original concentration in crystalline form.

In olfactometer tests recrystallized solid fractions (MP 72 - 73° C.) from trimedlure had little or no attraction for the Medfly, while a purified solid sample with a melting point of 57 - 58° C. proved very attractive both initially and residually. At least, two solid isomers may be present in trimedlure - one definitely more attractive than the other. This may account for the variability observed in field tests of different lots of trimedlure when crystallization occurred. In the early tests, crystallized material remained as effective as the liquid but more recently the crystalline form has lost practically all attraction after 6 to 7 weeks' exposure in the field. A field test of the solid and liquid fractions of trimedlure separated from the same production lot confirmed the laboratory results.

Celotex wafers treated with methyl eugenol plus 3% dibrom and then exposed on the soil for three months in sunny and shaded areas in the Bonin Islands retained approximately 55% of the effectiveness of freshly treated wafers. Those exposed for 5 months in the sun were still 17% as effective as fresh wafers. The efficiency of treated wafers stored for 12 weeks in the aluminum canisters used when making lure drops was not affected.

When methyl eugenol, cue-lure, and trimedlure were combined in the same trap there was no reduction in catches of melon fly but a significant reduction in catches of oriental fruit flies and Medflies. When one species was unusually scarce the lure for that species had less of a depressive effect on the other catches than when the species was abundant. In other tests the presence of methyl eugenol may have added to, but rarely detracted from, the attractiveness of cue-lure to the melon fly. Cue-lure greatly depressed the attractiveness of methyl eugenol to the oriental fruit fly. Trimedlure had a much less suppressive effect on the performance of cue-lure than on methyl eugenol. Medfly catches

may be inhibited slightly by the presence of cue-lure and the catches of this species are depressed even more by the presence of methyl eugenol. Despite the depression in trimedlure efficiency resulting from its use in multiple lure traps, it was as effective in such traps as the most attractive angelica seed oil used alone. As previously reported, the most efficient method of utilizing the three lures is together in the same trap rather than in three separate traps.

An important need is a more effective lure for the Mexican fruit fly, especially one that will be effective when used in a dry trap. The 1,369 coded compounds supplied during the year by the Pesticide Chemicals Research Branch made a total of 5,384 ENT compounds which have been tested in the lure screening program thus far, in addition to more than 510 fermentation products, including 360 supplied by the Northern Utilization Research and Development Division in 1961. Of all these materials one fermentation product in combination with 8% light brown sugar showed considerable attractiveness in recent tests and will be tested further.

Enzymatic hydrolysates of meat, soybean, and cottonseed gave promising results in the olfactometer, with the cottonseed material ENT-44,014-X being most attractive. In mango orchards, cottonseed hydrolysate was also most effective, giving catches at seven locations during 53 trap-weeks 1.46 times as large as those obtained with the standard Staley's protein insecticide bait No. 7 (SIB-7). The latter is an acid hydrolysate of corn protein mixed with corn steep liquor. Like other proteins cottonseed hydrolysate putrefies, causing discoloration of trap liquids and disintegration of soft-bodied insects such as fruit flies. Addition of borax at the 2% level eliminated these difficulties, and increased catches by 12%. SIB-7 with borax is now being used in all traps in the fruit fly detection program in California.

An attractive fermentation product, ENT-191 F W.C., added to SIB-7 at 1% increased the catch to 2.51 times that of SIB-7 alone.

Among 112 miscellaneous products tested in the field, Bovril, a beef consomme containing hydrolyzed beef protein and yeast extract among other components, was most attractive, but none of the ingredients of Bovril either alone or in combination caught as many flies as the original material.

Dry traps have not been effective when baited with currently available Mexican fruit fly lures. When traps containing ammonium hydroxide on wicks suspended over liquids were maintained at 60

and 30% R.H., catches were reduced sufficiently to suggest that relative humidity may be a factor in the attractiveness of Mexican fruit fly lures. Chlordane-lindane and methoxychlor-BHC-toxaphene-malathion mixtures suspended in small cloth bags in invaginated traps baited with standard lures, reduced catches from 34 to 89%.

The invaginated plastic trap reported on in 1960 continued to be most effective of twenty-two designs tested in 1961.

3. Miscellaneous Insect Pests of Subtropical Fruits. Mango seed weevils exposed to 10,000 r and above of gamma radiation in Hawaii died within 8 months and failed to lay eggs. There may be some recovery at 7500 r. No eggs were laid by weevils irradiated at 7500 or 50,000 r. Common mangoes stored in a tightly closed plastic bag at 32 - 36° F. remained firm and sound for 90 days. This assures a continuing supply of fruit in the off-season for use in mango weevil tests.

F. Evaluation of Equipment for Insect Detection and Control

1. Citrus Insects and Mites. In Florida, aerial applications of toxaphene dusts and emulsifiable concentrates were effective in controlling the citrus rust mite, being particularly effective against the active stages.

2. Subtropical Fruit Flies. Vaporization of ethylene dibromide (EDB) with an electric stove is a common practice in commercial fumigations, but this procedure causes corrosion of heaters and connections and may be responsible for operational failures. A gravity flow method for applying ethylene dibromide, developed in Mexico City in cooperation with the Plant Pest Control Division, in which the liquid fumigant is volatilized by introducing it into a high velocity squirrel cage fan, was as effective as vaporization with heat.

G. Insect Control Treatments for Commodites Regulated by Plant Quarantine

1. Subtropical Fruit Flies. Ten of 32 compounds tested in the fumigant-screening program in Hawaii were selected for further testing. Five were effective against both eggs and larvae and 5 principally against larvae. Amyl iodide and 1,2-dibromo-propane gave good results when tested in aqueous dips. None of the materials tested approached ethylene dibromide or ethylene chlorobromide in effectiveness.

Increasing the oxygen content of air to 75% or over during fumigation increased the effectiveness of methyl bromide against naked fruit fly eggs. This furnishes an important lead in the search for methods to improve fumigation techniques and decrease phytotoxicity.

A 5-minute aqueous dip of EDB at 1058 mg./l. at 80° F. was completely effective against oriental fruit fly in papaya. This short period treatment promises to be an extremely useful quarantine treatment. Papayas were not injured by effective dosages. Since heat was not involved, the dip failed to retard development of storage rots in papaya, but it may be used advantageously for other fruits with good keeping qualities. Harven or DHA-S, antimicrobial agents from the Dow Chemical Company, increased the shelf life of papayas since they remained firmer and less moldy after 5-minute treatments at concentrations of 2 or 4% actual ingredient in aqueous solutions. These materials could be incorporated in aqueous dips of EDB or ethylene chlorobromide for 5-minute treatments at 80° F.

Five-minute and 20-minute dip treatments at 115° F. with ethylene chlorobromide were determined for use as alternate treatments for ethylene dibromide. Dosage-mortality curves calculated from 126 tests with over 6,000 papayas infested with nearly 700,000 oriental fruit fly eggs and larvae, indicated that 222.4 mg./l. for the 20-minute dip and 744 mg./l. for the 5-minute dip will give complete kill of fruit flies. These treatments were also non-injurious to papayas.

Williams hybrid banana, a Cavendish mutant introduced from Australia, was very tolerant to fumigation with EDB at a dosage of 0.5 pound per 1000 cubic feet for 2 hours at 70° F. Fruits were severely injured when fumigated with methyl bromide at 2 pounds per 1000 cubic feet for 3 hours.

The favorable response of a number of local Hawaiian avocado varieties to fumigation with methyl bromide and the effectiveness of this treatment against fruit flies indicates promise of this material for quarantine use at a dosage of 2 pounds per 1000 cubic feet for 4 hours at 70° F. The varieties Kahaluu and Kashlan were uninjured by treatment. Linda, Tumin, Haas, and two seedlings showed superficial skin blemishes which were masked by a normal purple color upon ripening. The varieties Beardslee and Zutano showed moderate skin scald but no internal damage or effect on taste. The treatment cannot be used on Fuerte, Rincon, and Bacon varieties which ripened unevenly, developed browning of tissue surrounding the seed cavity, or decayed rapidly because of severe skin injury.

Two vertical or horizontal slits 1/8", 3/32", or 1/4" wide by 2" long on each of 4 sides of cartons containing fumigated papayas permitted entry of fruit flies and reinfestation when the cartons were exposed to infestation.

Fumigation of oranges packed in standard orange cartons at 50° F. with EDB would require at least 24 ounces/1000 cubic feet for 2 hours according to mortality data obtained with medfly infested papayas similarly packed at time of fumigation. EDB residues in Hawaiian navel oranges were 11.1 and 2.9 p.p.m., one and three days after fumigation when stored at room temperatures of 77 - 85° F. Inorganic bromides increased to 5.4 p.p.m. in 4 days. Results were similar to those for prepacked papayas fumigated with the standard dosage at 70° F.

Ethylene chlorobromide is more promising than EDB for fumigation of sweet peppers of the Yolo Wonder variety infested with melon, oriental, and Mediterranean fruit flies. The estimated dosage at probit 9 is 19 ounces/1000 cubic feet for 2 hours at 70° F. for EDB. Sixty-seven to 75% of the peppers so treated became unmarketable after 5 days. Though tests were few, there was indication that a lower dosage could be used with ethylene chlorobromide and that the tolerance to this fumigant would be higher.

In tests continued on summer squash (Bush scallop), a dosage of approximately 6 ounces/1000 cubic feet for 2 hours at 70° F. was necessary to destroy infestations of melon, oriental, and Mediterranean fruit flies. More data are needed to recommend application of the standard treatment developed for zucchini squash to this commodity.

Most of the work on ethylene dibromide in Mexico in 1961 had as its object the development of procedures and schedules better suited for use in emergency situations than those now available. Possibilities for short period ethylene dibromide fumigation were explored in tests involving treatment of 2.5 tons of grapefruit containing 8,400 larvae and nearly 1 ton of mangoes containing 75,000 eggs and larvae. After exposures for 15 minutes at temperatures of 65° to 72° F., there were 4 and 3 survivors at the 24- and 32-ounce grapefruit dosages, and 7 and 1 survivors at the 16- and 24-ounce mango dosages. Since amounts of fumigant used were much higher than those ordinarily employed in 2-hour fumigations, no effort was made to obtain tolerance and residue data.

Short period fumigation, consisting of introduction of vaporized ethylene dibromide into fumigation chambers under 2 to 8 inches of vacuum followed by immediate removal of fruit, was evaluated

at dosages of 4 to 32 ounces per 1000 cubic feet, both with and without circulation. Adequate kill of the Mexican fruit fly was not obtained in mangoes even at the highest dosage. After fumigation of mangoes containing 59,800 eggs and larvae under a polyethylene (6 mil) tarpaulin, there were 3 survivors at 8 ounces, 2 at 12 ounces, and none at 32 ounces per 1000 cubic feet. A blower provided circulation and the floor was unpainted smooth cement. Other tarpaulin fumigations with ethylene dibromide suggested that about 20 ounces would be required for security kill. Before EDB fumigation under tarpaulins can be considered as a method for treating loaded trucks, sorption by the truck body or trailer and possible effects of lubricants on fumigants will need to be evaluated.

Dosage-mortality data on an in-package treatment of fruit with EDB were previously obtained at 74° F. In recent tests with grapefruit at 50°, 74°, and 90° F. with dosages of 0.36 ml. and 0.48 ml. per carton for 24 hours, mortalities were approximately 99% or better regardless of temperature or dosage.

The investigation of ionizing radiation as a possible substitute for fumigation, heat, or cold treatments to disinsectize fruits, vegetables, and baggage has been promising enough to justify continued attention. Pending development of equipment to permit application on a quasi-commercial scale, work on this project in Honolulu, Hawaii, has been limited to a few infested host and tolerance tests. Tomato varieties Anahu, Step 346, and N-51 tolerated 25,000 and 50,000 r of gamma radiation. The tomatoes turned soft after exposure to 100,000 r. Green fruits were more tolerant than ripe fruits. Only the sound fruits stored well after irradiation. Williams hybrid bananas were scalded when exposed to from 10,000 to 50,000 r of gamma radiation, but ripened well and were palatable after storage at room temperature. Treatment accelerated ripening. Fully colored Haden and Pirie mangoes showed no injury when exposed to 100,000 r. Mature green fruits tolerated no more than 15,000 r, and one-quarter ripe and one-half ripe fruits tolerated 25,000 to 50,000 r with little or no ill effects except accelerated ripening. Ten fruit fly parasites, Opius oophilus and O. longicaudatus, were more resistant to gamma radiation than either the Mediterranean fruit fly or the oriental fruit fly. Tests conducted with field-infested yellow and strawberry guava, ball kamani, false kamani, hog plum, and Terminalia chebula showed that 5.4% of the parasites exposed to 8,000 r emerged as adults. Only 0.1% of oriental fruit flies and Medflies developed to the adult stage. An exposure of 10,000 r prevented emergence of flies or parasites.

When gamma radiation was applied to mature laboratory-reared Mexican fruit fly larvae for varying periods at the rate of 136 r per minute, radiation of 5,400 larvae indicated that probit 9 security for naked larvae would require a dosage of approximately 1,900 r. When infested mangoes were treated with radiation from cobalt 60 at dosages ranging from 500 r to 5,000 r at the rate of 1,500 r per minute, no oviposition was recorded from flies surviving the 1,000 r dose. Only 1 malformed male survived at each of the 2,000 r and 2,500 r treatments and there were no recoveries at 3,000 r or above.

2. Deciduous Fruit Insects. Further progress was made at Hoboken, N. J., in the development of a fumigation treatment for plum curculio in apples and other fruits needed as a condition for movement of these fresh fruits to west coast markets. In small-scale tests, methyl bromide, 2 pounds alone, or 1½ pounds in combination with ½ pound of ethylene dibromide, again gave complete kill of plum curculio larvae infesting mature Jonathan apples when exposures were 1¾ hour near 72° F. or 3½ or 3 hours respectively, near 53° F. under load. Complete kill was obtained of apple maggot larvae and eggs, confirming previous results. Good efficiency against plum curculio in infested mature plums was again indicated. Methyl bromide-ethylene dibromide mixture was more effective against plum curculio than methyl bromide alone at temperatures near 41° F. These results were similar to previous findings at temperatures near 52° F. At temperatures between 32° and 39° F., the adults exhibited high resistance to methyl bromide with survivors occurring after exposure to 3 pounds per 1000 cubic feet for 5 hours or less. Progress was also made in the development of a fumigation treatment for eastern blueberries infested with plum curculio or blueberry maggot. Ethylene dibromide alone in either warm or cool fumigations (without load) was somewhat more effective than methyl bromide alone. The combination of ½ pound of ethylene dibromide with 1½ pounds of methyl bromide had its usual high efficiency against larvae. Older pupae continued to survive various schedules in both apples and blueberries. Cranberry fruitworm larvae in blueberries were quite susceptible to methyl bromide, low schedules giving complete kill.

The tolerance of Chilean and other fruits to methyl bromide fumigation at cold temperatures near 40° F. (a treatment in wide, practical use since 1954) was reviewed. Previous tests at Hoboken had shown that Chilean plums, South African grapes and apricots, U. S. peaches, plums, grapes, and green pears have good tolerance, and results with several commercial varieties of apples, including Red and Golden Delicious, were also satisfactory. Mature pears were severely injured, and the tolerance of MacIntosh apples

was questionable. In 1961 two varieties of Chilean grapes (Almeria and Emperor) demonstrated good tolerance to methyl bromide.

3. Miscellaneous Crops. In fumigation tests in Hawaii, New Zealand asparagus tolerated up to 6 pounds of methyl bromide per 1000 cubic feet for 2 hours at 59° or 70° F. without injury or effect on flavor. The dosage of 8 pounds at 59° caused the asparagus to turn dark green when cooked and flavor was altered. Fumigation is required to guard against introduction of a New Zealand mite. The bean butterfly, Lampides boeticus, in Crotolaria sp., and the bean pod borer, Marcus testulalis, in green beans were killed by fumigation with methyl bromide at a dosage of 0.5 pound per 1000 cubic feet for 2 hours at 70° F. in tests conducted in Honolulu for the Plant Quarantine Division.

Evergreen tree seeds, including Scotch, mugho and Australian pine, demonstrated good tolerance to methyl bromide fumigation in 1961. The seeds were set for germination two to six weeks after treatment. In 1960 some injury was noted after 8 months of warm storage in Geneva, N. Y.

Cabbage from New York showed good tolerance to methyl bromide at dosages up to 5 pounds per 1000 cubic feet for 3 hours, NAP, or 3 pounds for 2 hours under 15 inches vacuum at temperatures near 51° F. Slight injury evidenced by necrotic spots near the mid-ribs of the inner leaves occurred after a 6-pound, 5-hour, NAP, 42° schedule. These and earlier tests on cabbage from Israel gave substantial evidence of the safety of the present treatment.

In further small-scale tests, at the New Jersey port of entry, with gall midge larvae, Phytophaga sp., intercepted by the Plant Quarantine Division in imported spruce seed, HCN fumigation again showed promise. These larvae had previously been resistant to methyl bromide - possibly due to a diapause condition. Carbon tetrachloride (a saturated atmosphere containing about 58 pounds per 1000 cubic feet near 75° F.) and dry heat (10 minutes at approximately 130° - 132° F.) also had good efficiency. Acritet (34% acrylonitrile and 66% carbon tetrachloride) at 4 pounds for 10 hours under high sustained vacuum with load, permitted some survival.

Tests in New Jersey and Maryland indicated that two varieties of narcissus bulbs (Tunis and First) had good tolerance to methyl bromide even when fumigated approximately five months after harvest. Small-scale forcing tests of the bulbs showed no injury to the flowers or leaves by the treatment for bulb scale mite after 2½ hours of fumigations at 65° with up to 4 pounds of methyl

bromide at NAP, high sustained vacuum, or vacuum reduced to NAP after ½ hour or after two NAP fumigations made at a 2-week interval. At Beltsville in fumigated bulbs held for forcing, complete control of the bulb scale mite was attained except at the 2-pound NAP dosage. Bulbs held at Hoboken for approximately three months showed extremely high mite mortality but in some cases some mite eggs appeared to have survived. These variable results are similar to some previous findings. Preliminary tests with methallyl chloride, HCN, carboxide or methyl acetate showed little promise for practical use at near or beyond the bulb tolerance limits.

4. Snails. In recognition of continuing needs of the Armed Forces and Plant Quarantine Division, further work was done at Hoboken, N. J., on quarantine treatments for estivated Cochlicella and Theba snails intercepted on military and other cargo from Mediterranean areas. Substantial numbers survived over eight months of very dry storage without food or water. A mixture of ethylene oxide 10% and carbon dioxide 90% (carboxide) continued to show good efficiency at warm and cool temperatures. Carboxide was recommended at 22½ pounds per 1000 cubic feet for 72 hours at 70° F. or above, and 27½ pounds at 55° - 69° F. for large scale trials under direction of the U. S. Armed Forces Pest Control Board. Further tests with sulfuryl fluoride (Vikane) confirmed its efficiency as a snail fumigant at warm temperatures but this material failed repeatedly at cool temperatures near 55°. HCN again showed good efficiency and high vacuum fumigation schedules of 2½ pounds for 6 hours for Theba pisana and 16 hours for Cochlicella were suggested for emergency use. Methyl bromide continued to show good efficiency against snails at cool temperatures. Tentative schedules have been recommended. Fumigation resistance noted in 1961 in naturally estivated snails was similar to that for 1960 snails. Estivated snails were again found to be more resistant than reactivated snails. Carbon tetrachloride at high dosages showed good efficiency as a treatment. A new Cochlicella snail, C. conoidea, intercepted in test shipments was about as resistant as C. barbara in preliminary tests.

In New Jersey tests, carbon tetrachloride at natural atmospheric pressure, and HCN and acrylonitrile under high vacuum, showed some promise for control of small, juvenile snails, Helicella sp., intercepted in Rosmarinus seed shipments. The problem presented by this snail is complicated by the fact that any suitable treatment must also be tolerated by the seeds. Methyl bromide fumigation at the usual seed schedule was not completely effective. Carbon tetrachloride at saturated concentrations in the atmosphere (near 58 pounds per 1000 cubic feet) with a 16-hour overnight exposure, has long been an alternate treatment for small

lots of infested seeds but little if any information on its effect on seed germination has been available. In recent tests, white clover, alfalfa and kudzu-vine seeds tolerated carbon tetrachloride even after a 72-hour fumigation period. In the case of clover seed, germination was good after seven months' storage. The carbon tetrachloride treatment may not be tolerated so well by other plant materials since a 16-hour fumigation in an atmosphere saturated with this material killed rhizomes of A. ulvaceous, an aquatic plant.

5. Fumigation Facilities. Tests at Hoboken, N. J., indicated that two coats of either ordinary shellac or an aluminum paint (either asphalt or linseed oil base) will reduce methyl bromide sorption loss on raw wood. Two brands of spar varnish and a rubber-base, latex paint were less effective. Three tests of wood samples painted nearly four years previously with one coat of two types of epoxy paints (Senox and Devran) or two coats of phenolic liner varnish or oil base enamel again gave good results.

Unpainted wood sorbed substantial amounts of methyl bromide each time more gas was added to the fumigation chamber in tests at Hoboken, N. J. The additions of gas are often required to maintain minimum gas concentrations. Sand, vermiculite, and perlite, which are now being used as plant packing materials, seemed to sorb little methyl bromide and gas penetration into them was generally good. Indications are these materials will not interfere with methyl bromide fumigation.

H. Varietal Evaluation for Insect Resistance

1. Subtropical Fruit Flies. Three varieties of avocados (Bacon, Fuerte, and Zutano) grown in California and then shipped to Hawaii were susceptible to oriental fruit fly infestation when exposed to 5,000, 15,000 or 100,000 caged flies for periods of $2\frac{1}{2}$ to 16 hours.

I. Insect Vectors of Diseases

1. Citrus. Emphasis is continuing at Orlando, Fla., on studies of factors influencing spread of the tristeza virus by aphids. Low transmission efficiency makes it difficult to draw conclusions. Experiments thus far have failed to substantiate indicated differences between the vector efficiency and sources of virus inoculum but there is increasing evidence of a difference in efficiency among colonies of the melon aphid as vectors.

Melon aphids transmitted the virus from citrus thorns. Negative results in tests with spirea aphids confirmed earlier indications

that this aphid is an inefficient vector of tristeza. In additional tests, neither the citrus whitefly nor the green peach aphid transmitted tristeza. Two species of sharpshooters are considered possible vectors of citrus blight. Disposable traps caught equal numbers of both species in the spring but Homalodisca coagulata outnumbered Oncometopia undata by about 10 to 1 in the fall. Catches were low in the summer. Methods of rearing these species for vector tests are underway.

The citrus whitefly and green peach aphid did not transmit tristeza virus in a limited number of additional tests. Experiments with the citrus red mite are awaiting possible symptom development. Other vector tests initiated during the year included xyloporosis transmission with spirea aphids, exocortis transmission with spirea aphids and a leafhopper, Homalodisca coagulata, and citrus blight transmission with this same leafhopper and citrus mealybugs. No symptoms of xyloporosis, exocortis, or citrus blight have developed in previous experiments involving these viruses, all of which have unusually long incubation periods.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Munger, F., and Gilmore, J. E. 1960. Mass production of the citrus red mite. Jour. Econ. Ent. 53(5):964-966.

Insecticidal Control

Burditt, A. K., Jr., Selhime, A. G., and Spencer, H. 1962. Field evaluation of certain materials on citrus mites. Citrus Industry 43(1):22, 28, 29.

Burditt, A. K., Jr., Selhime, A. G., and Spencer, H. 1962. Field evaluation of experimental materials on citrus mites. Proc. Fla. State Hort. Soc. 74:38-43.

Cressman, A. W. 1961. Scale, mite pest studies at U.S.D.A. Riverside Unit, Calif. Citrograph 47(1):15-17.

Cressman, A. W., and Gilmore, J. E. 1961. Screening tests of organic insecticides against California red scale, second report. U. S. Dept. Agric. ARS 33-68.

Munger, F., Gilmore, J. E., and Cressman, A. W. 1960. Studies of citrus red mites resistant to demeton and ovex and their responses to Tedion and Kelthane. Jour. Econ. Ent. 53(3):384-388.

Shaw, J. G. 1961. Airplane applications of malathion bait spray for Mexican fruit fly control. Jour. Econ. Ent. 54(3):600-601.

Shaw, J. G., and Riviello, M. Sanchez. 1961. Exploratory studies with soil toxicants to control the Mexican fruit fly. Jour. Econ. Ent. 54(4):666-668.

Biological Control

Cressman, A. W. 1961. Scale, mite pest studies at USDA, Riverside Unit Calif. Citrograph 47(1):15-17.

Muma, H., Selhime, A. G., and Denmark, H. A. 1961. An annotated list of predators and parasites associated with insects and mites on Florida citrus. Univ. of Fla. Tech. Bull. 634.

Munger, F., Gilmore, J. E., and Cressman, A. W. 1960. A disease of the citrus red mite. Sunkist Pest Cont. Circ. Jan.

Smith, K. M., and Cressman, A. W. 1962. Birefringent crystals in virus diseased citrus red mite. Jour. of Ins. Path. 4(2):229-236.

Insect Sterility, Attractants, and Other New Approaches to Control

Beroza, M., Green, N., Gertler, S. I., Steiner, L. F., and Miyashita, D. H. 1961. New attractants for the Mediterranean fruit fly. Jour. Agric. and Food Chem. 9(5):361-365.

Burditt, A. K., Jr. 1961. Some new approaches in the control of insects. Citrus Industry 42(10):20, 21.

Christenson, L. D. 1962. Atomic energy to control insects. U. S. Dept. Agric. Yearbook, 1962, p. 348-357.

Rhode, R. H., Lopez, D. F., and Equisa, F. 1962. Effects of gamma radiation and exploratory overflooding with sterile flies on laboratory populations of the Mexican fruit fly. Jour. Econ. Ent. 54(1):202-203.

Steiner, L. F., Rohwer, G. G., Ayers, E. L., and Christenson, L. D. 1961. The role of attractants in the recent Mediterranean fruit fly eradication program in Florida. Jour. Econ. Ent. 54(1):30-35.

Steiner, L. F., Mitchell, W. C., and Baumhover, A. H. 1961. Symposium on isotopes application in the soil and crop sciences, Tenth Pacific Science Congress. Special Issue Internat. Jour. Applied Radiation and Isotopes.

Evaluation of Equipment for Insect Detection and Control

Shaw, J. G. 1961. Airplane applications of malathion bait spray for Mexican fruit fly control. Jour. Econ. Ent. 54(3):600-601.

Insect Vectors of Diseases

Norman, P. A., and Grant, T. J. 1961. Variation in aphid transmission of tristeza virus. Proc. 2nd Conf. of Internat. Organ. of Citrus Virologists, p. 126-131.

AREA 5. FORAGE AND RANGE INSECTS

Problem: Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and stink bugs, the alfalfa weevil, root borers, spittlebugs, and a variety of aphids including the spotted alfalfa aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of nonchemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Florala, Ala. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. The field station at Bakersfield, Calif., was closed and the work on alfalfa insects at that location transferred to Tucson, Ariz., in January 1962. Research on clover insects at Forest Grove, Oreg., is conducted

in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Studies on varietal resistance, insect vectors of plant diseases and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), NC-38 (The Spotted Alfalfa Aphid), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops) and S-25 (The Biology and Control of Insects and Mites Attacking Forage Crops). A P.L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" with the Research Institute of Plant Protection, Poznan, Poland, was activated in March 1962.

The Federal scientific effort devoted to research in this area totals 25.7 professional man-years. Of this number 3.6 man-years are devoted to basic biology, physiology and nutrition, 5.0 to insecticidal and cultural control, 5.6 to insecticide residue determinations, 3.8 to biological control, 0.8 to insect sterility, attractants and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 4.8 to varietal evaluation for insect resistance, 0.5 to insect vectors of diseases and 1.1 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 43.9 professional man-years divided among the subheadings as follows: 14.6 on basic biology, physiology and nutrition, 13.9 on insecticidal and cultural control, 10.2 on insecticide residues, 0.8 on biological control, 0.4 on insect sterility, attractants and other new approaches to control, 0.5 on evaluation of equipment for insect detection and control, 2.4 on varietal evaluation for insect resistance and 1.1 on insect vectors of diseases. Ten States are cooperating on research on grasshopper populations involving two regional projects, W-37 for conditions on western rangelands and NC-52 for the Great Plains Area. Five Mid-Western States are conducting research on the spotted alfalfa aphid under regional project NC-38. Three Western States are also studying the biology of this pest. Studies on the pea aphid and other aphids are also underway. Six Western States are cooperating on studies on the alfalfa seed chalcid under regional project W-74. Ten Southern States are cooperating in a study on the biology and control of forage insects and mites (regional project S-25). The migration of the potato leafhopper is being investigated. Harvester ants are being studied at some of the Western Stations. Six States are searching for effective insecticides for the spotted alfalfa aphid; four States have insecticide programs on control of pasture insects; and six are studying insecticidal control of legume seed insects.

State Experiment Stations are investigating harvest residues and dissipation rates of insecticides on forage plants. Several States are evaluating native and introduced parasites, predators, and insect pathogens for control of aphids, alfalfa weevil and alfalfa seed chalcid. Studies are in progress on chemosterilants. Improvements in spraying and dusting equipment are being studied in cooperation with agricultural engineers. Research is underway in the Northwest to determine whether insects are responsible for causing silver top of grasses. A number of States are studying the relationship of root insects and root diseases of forage plants.

Industry and other organizations including growers also contribute to the research on forage and range insects. Chemical companies develop and screen insecticides and several of them conduct insecticide field-testing programs. Growers cooperate by supplying fields and crops for experiments against forage insects. Estimated annual expenditures are equivalent to approximately 10 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE RESEARCH

A. Basic Biology, Physiology and Nutrition

1. Grasshoppers. Grasshopper surveys and observations made in 1961 from Mesa, Ariz., on rangeland in five plant habitats showed that populations had declined drastically since 1960. The decrease came in the second consecutive year of unusually low precipitation and unfavorable vegetation. Aulocara elliotti replaced Melanoplus sanguinipes as the dominant species in the nymphal survey in June and was the leading species in the adult survey in July. Habitats consisting of grass and Juncus meadows, comprised mainly of perennials, remained succulent and maintained populations to a greater extent than habitats such as forbs, mixed grass and forbs and weedy and grassy margins in which annuals were abundant.

Grasshopper surveys were made in Arizona in 1961 for the fourth successive year to observe the trend of the populations on Conservation Reserve land. In June the average nymphal population on such land was 0.3 per square yard compared with 2.9 in 1960. In July the average adult population was 0.2 per square yard compared with 2.5 in 1960. Decreases in the other habitats ranged from 59 to 94% and were roughly proportional to those in Conservation Reserve land. The decrease in 1961 followed 3 consecutive years of substantial population increases on such land and was probably caused by unusually dry weather and poor vegetation.

There was no desert grasshopper (Trimerotropis p. pallidipennis) infestations of economic importance in Arizona in 1961 due to below normal precipitation and vegetation. The spring population average

was much lower than in 1960, but improved vegetation conditions during the summer were beneficial and the early fall population was somewhat higher than in 1960. There were two generations of the insect. The first hatched from February 15 to March 31 and the second from August 10 to October 1. Adults were present in all months; nymphs in all except June and July; and gravid females in all except May, June, and July. The non-gravid period coincided with a period of very hot weather and predominantly dry vegetation. Dipterous larvae and mites parasitized a small percentage of the adults.

Under insectary conditions at Mesa, the average longevity of the desert grasshopper was 61.7 days for females and 63.2 days for males. The number of egg pods averaged 11.2 per female, and the number of eggs per pod averaged 34.5. At a mean temperature of about 93° F., the average incubation period was 15.5 days. At a mean temperature of approximately 91° F., the nymphal period for 82 males averaged 31.2 days, and for 84 females 33.3 days.

Twenty pairs of the desert grasshopper were fed succulent alfalfa, johnsongrass, head lettuce, and alfilaria while 20 comparable pairs were fed air-dry alfalfa, johnsongrass, head lettuce, and alfilaria, and water supplied them. Females fed the succulent diet lived an average of 56.4 days and deposited an average of 6.05 egg pods compared with 39.4 days and 3.75 egg pods for females fed the air-dry diet. The average number of eggs per pod was 34.4 and 33.0 for the respective groups.

Plants of 25 species were exposed August 15-18 to late-instar nymphs of the desert grasshopper in screen cages in the insectary at Mesa. Some of the most favored plants were head lettuce, Kallstroemia grandiflora, bermudagrass, johnsongrass, Tidestromia lanuginosa, spurge, side-oats grama, and chinch-weed. Relatively few nymphs fed on horseweed, spiderling, sunflower, mesquite, Franseria spp., and telegraph-plant.

Grasshopper populations in alfalfa fields in the Salt River Valley of Arizona averaged 0.41 per square yard in April 1962 compared with 0.17 in 1961. The migratory grasshopper (Melanoplus sanguinipes) was dominant with 72% of the total in 1962 and 84% in 1961. The desert grasshopper was second in abundance each year. In a summer 1961 survey Encoptolophus pallidus subgracillus replaced M. sanguinipes as the dominant species in alfalfa.

On the range recovery plots in Arizona during April-July 1961, the cumulative square-yard grasshopper population in both fenced and grazed check plots was 3.4 as contrasted with 0.7 in both treated plots. Initial populations were higher than in 1960 but decreased drastically owing to dry range conditions. Precipitation during the

winter and spring 1960-61 was about half of that recorded in 1959-60 and the perennial grass ground cover decreased on both fenced and grazed plots. Damage by grasshoppers to shortgrass on the fenced check plot was 43.4% as compared with 55.1% by both grasshoppers and cattle on the unfenced check plot. In a good grass area with good management practices, the perennial grass stand was less affected. For the April-July period, square-yard grasshopper populations in both fenced and grazed check plots were 2.1 as compared with 0.4 in both treated plots. Damage by grasshoppers on mixed grasses in the fenced check plot was 11.7% as compared with 39.3 by both grasshoppers and cattle on the grazed check plot.

At Bozeman, Mont., studies on the isolation of a factor in romaine lettuce (Lactuca sativa cv. "Romana") and hedge mustard (Sisymbrium irio) necessary for growth and development of Melanoplus bivittatus and M. sanguinipes were continued. Attempts were made to purify the growth factor by means of column chromatography with charcoal and Dowex 50, but all efforts to recover the activity from the column by elution with ammonia and hydrochloric acid failed. Purification of the growth factor was attempted using a charcoal column through which an extract was passed and eluting the column with varying concentrations of ethanol and 50% ethanol plus 2% concentrated ammonium hydroxide. None of the individual fractions from this procedure (charcoal effluent, ethanol eluate, ethanol-ammonia eluate) was active. However, recombination of the fractions resulted in partial but not complete recovery of the former activity. These results suggest the possibility that more than one factor is responsible for the activity of plant extracts which would account for the activity of the recombined fractions. A multiple factor would also help to explain why it has been so difficult to effect a purification.

Many authors have reported differences in the effects of various food plants on growth of grasshoppers. In order to determine whether these differences would also be apparent when extracts of plants were added to the basic diet, extracts of johnsongrass, bermudagrass, mustard, and nettleleaf goosefoot were prepared in the same way as for romaine lettuce. A comparison was made on the basis of a submininal amount of lettuce extract. Mustard proved best, followed by lettuce, nettleleaf goosefoot, bermudagrass, and johnsongrass.

Work was continued at the Bozeman laboratory on the causes for the deformed wings which appear in a varying but usually small number of laboratory-reared adults. Disease was suspected at first since a twisted wing condition is often associated with protozoan infection in grasshoppers. However, in three collections of specimens sent to the University of California Insect Pathology Laboratory, no disease organisms were found. Emphasis was then placed on the physical conditions of the rearing technique, mainly crowding, light,

and temperature. Indications are that the more hoppers per cage the higher the percentage of abnormal adults but the data are inconclusive. Supplementary heat and light furnished by heat lamps suspended over the cages have also yielded inconclusive results. Use of the heat lamps has reduced the mortality in all tests. The abnormal wing development might be genetic but occurrence of this phenomenon in four species, Melanoplus bivittatus, M. sanguinipes, M. packardii, and Dissosteira carolina, indicates a physical rather than genetic cause.

2. Alfalfa insects. Preliminary tests at Beltsville, Md., indicate that diapause of adult alfalfa weevils can be prevented by rearing larvae under conditions of 10 hours or less of daylight. This would enable continuous rearing in the laboratory and approximately 4 generations per year compared with 1 in the field. Adults and eggs have been successfully stored in refrigeration up to four months, thus providing other means for maintaining a continuous supply of insects for laboratory and greenhouse tests. Attempts to find a suitable food substitute for rearing the alfalfa weevil in the laboratory have not been successful. Dried alfalfa meal alone and in combination with numerous additives, fresh alfalfa extracts, and artificial lepidopterous and dipterous diets were rejected. Observations by the Beltsville laboratory showed that alfalfa weevil adult populations produced in two fields of Conservation Reserve lands were 10 times greater than those produced in two cropped and sprayed fields. Populations were approximately 10 times greater in the Piedmont area than in the mountain area.

Dispersal studies at Beltsville showed that adult weevils left alfalfa fields in June and returned in mid-September to mid-November. Factors influencing flight from fields in June include light, wind velocity, temperature, population density, and food supply. Adults marked with fluorescent paint and released in alfalfa fields in mid-June, were observed in flight immediately after release and at night feeding on plants near release sites, but none were collected in systematic samples taken in surrounding areas in mid-summer. Collection of unmarked weevils up to 5,000 feet distant from alfalfa indicated a wide dispersal.

In the laboratory crosses between weevils from Maryland and Utah, eggs produced by eastern males crossed with western females were infertile whereas those from reciprocal crosses were fertile.

During the fall of 1960 true sexual forms and eggs of the spotted alfalfa aphid were found in Howard and Greeley Counties, Nebraska. The eggs hatched in mid-April 1961. Prior to this aphids were known to pass the winter only in the adult or nymphal stages and never north of Kansas. Aphids were readily found in these counties after April 1961 but owing to unfavorable weather, populations remained

until the first week in August when aphids migrated into the State from more southern areas. Moderate populations built up during the fall and light damage occurred in the area of the overwintering eggs and in the southwestern corner of the State, where the aphid is more generally a problem. In mid-October 1961, sexuales were collected in 22 Nebraska Counties and were reported in two adjacent South Dakota Counties. The percentage of sexuales in the adult population varied from over 60 in the counties where they were originally found to less than 1 in the county most distant. Thus, two types of aphids, one with the ability to produce sexuales in the fall and the other without this ability are present in the same fields in Nebraska. The numbers of males were low in all areas. The ability to overwinter as an egg in the northern limits of its range greatly increases the potential threat of this pest.

3. Clover Insects. Flight studies of the clover root curculio were conducted at Forest Grove, Oreg., to determine the time and number of flights and the importance of flight as a means of dispersion. A motor-driven trap designed to catch insects in flight was operated in a 2-year-old infested red clover field at intermittent intervals from March 29 to October 14. Flying curculios were taken from mid-September to mid-October, confirming results of the previous year. No weevils were taken in any other period. Enough weevils were collected to indicate that flight is an important factor in the dispersion of this insect. Most flying occurred when air temperatures were 80° F. or above.

Similar studies using sticky board traps to catch clover root curculios were conducted at University Park, Pa., from late August to mid-November. Adults were trapped between August 24 and October 20, indicating that flights occur on warm days during late summer and early fall.

At Lincoln, Nebr., early in the spring young larvae of the sweetclover weevil feed within the nitrogen nodules in the soil and older larvae probably feed on them. Larval development was nearly complete by late June and most new adults had emerged by mid-July. There was the possibility of a partial second generation.

In Nebraska, sweep samples were taken in both first and second year sweetclover fields every two hours during a 24-hour period about every two weeks. Overwintered sweetclover weevil adults were most active during the day, but newly emerged adults in July were more abundant at night. Very few adults were taken at any time of day during the late summer but they were abundant again at night in mid-October.

Among the natural factors influencing seasonal population fluctuations of the sweetclover aphid in Nebraska the greatest effect was caused

by predaceous insects (principally lady beetles). Heavy rains also were important, particularly when predator populations were high. These factors operated largely during the summer months and were responsible for low aphid populations at that time. Temperature was not a major factor at this time as it was possible to build up large aphid populations in the field when predators were controlled. Parasites were not important but an entomogenous fungus almost completely controlled aphid populations that were high following control of the predators.

4. Grass Insects. At Tifton, Ga., a study was undertaken to learn more about the biology and ecology of the spittlebug Prosapia bicincta which severely damages coastal bermudagrass. Adults were collected from early September to early December and held for oviposition records. During October and November over 3300 eggs were obtained.

During September, 87 females were dissected and only 40 possessed eggs in the ovaries. There were from 8 to 64 eggs per female, but only 3 to 5 of the eggs in any one individual were fully developed. These data suggest that the eggs undergo a long developmental period and that females lay them in small numbers.

The number of eggs laid per female varied from 84 to 141. Females probably lay from 5 to 10 eggs per day during the oviposition period of 12 to 14 days. Field-collected adults lived up to 5 weeks in the laboratory. Of 675 adults collected 43% were females.

Eggs were held in constant relative humidities of 100, 90, 85, and 56%. Also, eggs deposited in filter paper were held so that they were constantly in contact with a film of moisture. These groups of eggs were placed in constant temperatures of 80, 70, 50 and 40° F. Eggs hatched at high humidities and high temperatures. At low humidities and high temperatures and at low humidities and low temperatures, eggs entered a diapause. A second test was conducted to determine the effect of dry conditions on diapause. Eggs laid in wet filter papers were allowed to dry and held 0, 1, 2, 3, 10 and 30 days, after which they were kept in contact with a film of moisture until they hatched. The dry period reduced the number of eggs hatching and high moisture conditions prevented diapause. In a third test a photo-period of 14 hours light and 10 hours darkness resulted in a longer incubation period and a lower percent hatch.

About eight days after the egg is laid a shiny black convex oval egg burster is formed which splits the chorion. About the 14th day, red eye spots and two red areas are visible in the abdominal region of the embryo. On the 17th day bright yellow nymphs with red eyes and red areas on the ventrolateral sides of the abdomen emerge. They are very active and when placed on a coastal bermudagrass stem move

toward the soil and soon disappear. They may go under the surface to feed. Based on head measurements, there are six nymphal instars.

At University Park, Pa., the principal insects of economic importance in timothy and bromegrass were several species of grasshoppers, the Japanese beetle, flea beetles, three different plantbugs, the meadow spittlebug, and five different leafhoppers. Timothy and bromegrass differed from orchardgrass sampled in 1959 and 1960 in supporting more Lygus lineolaris and Agallia constricta, while orchardgrass had the leafhoppers Ambysellus curtisii and Latalus savi.

The oviposition site of the sawfly, Dolerus sp., infesting orchardgrass was observed at University Park for the first time in 1961 in the margins of leaf blades. Oviposition occurred from late April to early May. Larvae started hatching in mid-May. Many full-grown larvae carried eggs of the wasp parasite, Tryphon seminiger, attached externally on their bodies when they entered the soil to aestivate. The eggs hatched and the parasite larvae fed on the resting sawfly larvae in their earthen cells.

To determine the amount of damage caused by adult meadow spittlebugs to orchardgrass, 100 adults were collected in the field at University Park and caged 14 days on potted grass. They reduced growth by an average of 1.8 inches and green weight by 1.4 grams.

B. Insecticidal and Cultural Control

1. Grasshoppers. During 1961 at Bozeman, Mont., 44 new compounds were tested in the laboratory against adult Melanoplus bivittatus grasshoppers. None was equal in toxicity to the aldrin standard. However, eleven of them were equally effective at twice the aldrin dosage. On the basis of their toxicity and availability, six of these were selected for field testing in 1961. These were Shell SD-3562 (ENT. 24482), Shell SD 4294 (ENT. 24717), Bayer 39007 (ENT. 25671), Guthion, Bayer 41831 (ENT. 25715), and Stauffer R-1504 (ENT. 25705).

Sixteen new compounds were tested in the laboratory during 1962. Of these Monsanto CP 40273 (ENT. 25786) was equal in toxicity to the aldrin standard and Monsanto CP 40294 (ENT. 25787) and Hercules 9699 were equal to the standard at twice the dosage.

During 1961 ten insecticides were field-tested in Montana on small plots as a continuation of the search for an insecticide that can be used safely on cultivated crops and rangeland where residues are a problem. The results showed that Shell SD-3562 was only slightly less effective than the standard (2 ounces of aldrin in 1 gallon of diesel fuel per acre) at dosages of 2, 3, and 4 ounces per acre. Shell SD-4294 at 16 ounces per acre was equal to the standard but showed no residual kill beyond the first 24 hours. Dimethoate at

4 ounces was equal to the standard and only slightly lower at 2 ounces per acre. Malathion (SF 60) at 12 ounces was equal, while diazinon (AG 500) at 6 and 10 ounces, was slightly inferior to the standard. Guthion at 8 ounces and Bayer 25141 at 4 and 8 ounces were as good or better than the aldrin treatment. Bayer 41831 and Bayer 39007 were equal to the standard at 8 ounces, while Stauffer R-1504 at 16 ounces per acre was inferior.

At Bozeman, Mont., Sevin was applied to medium (20 and 40 acres) and large (216 to 2,200 acres) plots by both small and large aircraft in tests against range grasshoppers. Dosages, formulations, droplet size, and volume of spray solution were studied in relation to grasshopper kills, with aldrin at 2 ounces per acre as a standard. Dimethoate and DDVP were tested on 40-acre plots for dosage comparisons only. Three formulations of SD-3562 were tested on 40-acre plots.

No difference in efficiency could be shown between the Sevin formulations 80-S in water and 85-P in oil. Using a tung oil sticker did not improve the results with the 80-S formulation. It was concluded that 1 gallon of Sevin spray solution per acre was just as effective as larger quantities. Dosages of 2 and 4 ounces of dimethoate or SD-3562 per acre gave efficient control but 4 ounces of DDVP did not.

In the 20- and 40-acre tests, 8 ounces of Sevin per acre gave effective control, but when applied to large plots by large aircraft kills ranged from 10 to 30% lower. Factors believed involved in the lower kills on large acreages were inability to fly completely accurate swaths, the effect of drift from one swath-end to the other, and the shorter residual effectiveness of Sevin.

2. Alfalfa Insects. At Beltsville, Md., granular heptachlor at the rate of 1.0 or 1.5 pounds per acre gave better alfalfa weevil control when applied in November than in October, and was better than heptachlor applied as a spray. Dieldrin at the same dosages gave slightly less control, and lindane at 1.0 pound provided no control. No heptachlor or heptachlor-epoxide residues were found on the crop at time of first cutting.

Combinations of recommended insecticides tested at Beltsville failed generally to provide better control of either alfalfa weevil or pea aphid than when the materials were used alone. The combination of malathion and methoxychlor (1.0 and 1.5 pounds) gave best control of the alfalfa weevil, and dimethoate (1.0 pound) gave best control of the pea aphid at 23 days following applications. The addition of a horticultural oil to sprays at the rate of 2 gallons per acre did not increase control of the alfalfa weevil but did increase pea aphid control.

Two new experimental insecticides, Stauffer R-1504 at 1.0 pound per acre and Geigy 30494 at 1-1/2 pounds, showed promise for control of the alfalfa weevil. At Beltsville, Md., both materials gave control equal to or better than heptachlor when applied as sprays to the spring crop. Geigy 30494 also gave good control of the pea aphid.

3. Clover Insects. At Forest Grove, Oreg., experiments were conducted to determine the minimum amount of granular heptachlor that would control the clover root curculio, the lesser clover leaf weevil, and the clover root borer. Applications were made March 18 on plots of inch-high clover at 1, 0.5 and 0.25 pound per acre. Stem samples taken May 19 showed that lesser clover leaf weevil larval damage was reduced 97% or more. Soil samples dug June 12-14 showed larvae of the clover root curculio were reduced 50 and 53% for the pound and half-pound rates, respectively, and 21% for the quarter-pound rate. Root samples dug August 30 showed that the number of roots infested by clover root borer was reduced 100, 97 and 88% for the pound, half-pound and quarter-pound rates, respectively.

Aerial applications of heptachlor at 1 pound per acre as an emulsion at Forest Grove in October 1961 caused a reduction of 93% in the clover root curculio larval population in June 1962. A comparable treatment applied with ground equipment caused a 98% reduction.

A test conducted at Lincoln, Nebr., during June indicated that plowing second year sweetclover stands before bloom will effectively reduce the sweetclover weevil larval population. This is in agreement with the agronomic recommendation that plowing be done when the plants are 6 to 8 inches tall. However, general farm practice is to wait until plants are in bloom.

4. Lesser Cornstalk Borer. At Tifton, Ga., granular formulations of several insecticides were tested to control the lesser cornstalk borer. The insecticides were applied in an 8-inch band over rows of seedlings 1 to 4 inches high. This type of application gave significantly better stand protection than application at planting time. On seedling millet, parathion, diazinon, phorate, dieldrin, endrin, Di-syston, Zinophos and methoxychlor at 2.0 pounds per acre gave from 80.4 to 92.4% seedling stand protection. The infestation on the untreated plots, 32.7% of the stand, was significantly higher than on the treated plots.

Granular endrin, dieldrin and diazinon at 1/2 and 2 pounds per acre applied to seedling cowpeas, corn and sorghum gave from 94.3 to 99.6% stand protection. Significant differences in control did not exist between the toxicants or the application rates. All treatments were significantly different from the untreated plots which showed an infestation of 10.1 to 20.2%.

Granular toxaphene at 2, 4 and 8 pounds per acre and dieldrin at 2 pounds were applied to seedling cowpeas. No significant differences existed between the treatments. The percent of stand protection ranged from 87.1 to 90.9. All treatments were significantly better than the control, in which 44.2% of the plants were infested.

5. Grass Insects. At Tifton, Ga., Sevin, Guthion, diazinon, endosulfan, dimethoate and Zinophos were applied to millet at the rate of 2 pounds per acre and samples of leaves from each plot were fed to 4-day old fall armyworm larvae. All of the materials gave 100% kill in 24 hours in samples taken immediately after treatment. One day after treatment all materials gave 100% kill in 24 hours except dimethoate. Two days after treatment only Sevin, Guthion and Diazinon gave 100% control. These same insecticides gave 100% control in samples taken through the fifth day except diazinon which gave only 40%. Guthion gave approximately 100% control through the 13th day.

6. White-fringed Beetles. At Florala, Ala., studies were continued to develop new and to improve current methods of insecticidal control of the white-fringed beetle in cultivated fields, nursery plantings, noncultivated land, and as treatments for commodities regulated by the quarantine. In pot tests exposed to outdoor weathering and natural temperatures, dosages of 2.5 pounds of chlordane in 403.3 cubic yards of soil (the upper 3 inches of an acre) gave complete mortality of newly hatched larvae for 3 years, the 5-pound dosage for 4 years, and the 10-pound dosage for 8 years. Dosages of 0.5 pound of aldrin gave complete mortality for 2 years, dosages of 1 pound for 9 years, and dosages of 2.5 pounds or more for 10 years. Dosages of 0.5 pound of dieldrin gave complete mortality for 4 years, dosages of 1 pound for 9 years, and dosages of 2.5 pounds or more for 10 years. Dosages of 0.5 pound of heptachlor gave complete mortality for 7 years, dosages of 1 pound for 9 years, and dosages of 2.5 pounds or more for 10 years. Dosages of 0.125 pound of endrin gave complete mortality of newly hatched larvae installed immediately after treatment, dosages of 0.25, 0.50, and 1.0 pound gave complete mortality of larvae one year after treatment, and dosages of 5 pounds gave complete mortality of larvae 5 years after treatment, but not in later years. Dosages of 5 pounds of endosulfan were required to give complete mortality of newly hatched larvae installed immediately after treatment, and the 5- and 10-pound dosages gave complete mortality of larvae installed one year after treatment, but not in later years.

In outside soil chambers, chlordane mixed into the upper 3 inches of soil in 1949 at rates of 5 and 10 pounds per acre gave complete mortality of newly hatched larvae for 6 years and dosages of 25 pounds for 11 years after treatment. Toxaphene mixed into the upper 3 inches of soil in 1949 at the rate of 10 pounds per acre gave

complete mortality for 5 years, 25 pounds for 11 years, and 50 pounds for 7 years. In outdoor soil chambers, aldrin, dieldrin, and heptachlor were mixed into the upper 3 inches of soil in July 1957 at rates of 0.5, 1, 3 and 5 pounds per acre. In 1960-61, the 0.5- and 1.5-pound dosages of aldrin, and the 0.5-pound dosage of heptachlor gave 99% control, and all other dosages gave complete mortality. Each soil chamber was infested with an equal number of newly hatched larvae of Graphognathus leucoloma fecundus and G. peregrinus in 1956 and through 1960. During the 5-year period of 1957-61, 363 G. leucoloma fecundus adults and 383 G. peregrinus adults emerged from the untreated chambers, while 66 G. leucoloma fecundus and 120 G. peregrinus adults emerged from the treated chambers. These studies suggest that there may be a difference in the susceptibility of the two species to soil treatments.

In randomized field plots on cultivated land, dieldrin in granular and powder formulations was applied broadcast and disked into the upper 3 to 4 inches of soil in March 1953 at rates of 1, 2.5, and 5 pounds per acre. All rates of treatment gave drastic reductions in populations in 1954 and 1955, and gave complete control in 1956-1958. Larvae were found in the plots receiving the 1-pound treatment in 1959, 1960, and 1961, in the plots receiving the 2.5-pound treatment in 1961, and in the plots receiving the 5-pound treatment in 1960 and 1961. Aldrin applied in a similar way at the same rates gave complete control in 1955 and 1956, but larvae were found in the plots receiving the 1-pound treatment in 1957-1961, and in the plots receiving the 2.5-pound treatment in 1959-1961. The 5-pound aldrin treatment gave complete control from 1954 through 1961. The granular and powder formulations of aldrin and dieldrin were equally effective.

Studies of the value of dieldrin surface treatments of azalea and camellia plants growing in a slathouse at Florala have been in progress since 1953, and of heptachlor surface treatments since 1956. Both granular and emulsion formulations of the two insecticides were applied at the rate of 5 pounds per acre on the soil surface around established plants. Dieldrin treatments have given better control than heptachlor but both have failed to eliminate all larvae from the plots.

C. Insecticide Residue Determinations

1. Dimethoate Residues on Bermudagrass. At Tifton, Ga., dimethoate was applied as an emulsion to bermudagrass at 4, 8, and 16 ounces per acre. Residues were 11.79, 28.01 and 65.19 p.p.m., respectively, 1-day after treatment and 0.61, 0.86 and 2.13 p.p.m., 16 days after treatment. Residues on the 70th day were 0.25, 0.19 and 0.37 p.p.m., respectively. However, only 0.97 inches of rain fell in the 70-day period and the grass during the latter part of the period had stopped growing and was almost dry.

2. Dimethoate residues on corn, corn silage and in milk of dairy animals fed treated silage. At Tifton, Ga., dimeothate was applied as an emulsion at 4, 8 and 16 ounces per acre to corn grown for silage. The residues on corn plants 1-day after treatment were 1.99, 4.07 and 4.84 p.p.m., respectively. Eight days after treatment they were 0.31, 0.71 and 2.05 p.p.m. On the 16th day the residues were 0.058, 0.100, and 0.192 p.p.m.

Corn was sprayed with dimethoate at 4, 8 and 16 ounces per acre, chopped immediately after treatment and packed in polyethylene silos. One silo was used for each treatment level and a fourth contained untreated corn. A sample of corn plants was taken for residue analysis immediately after application of the insecticide, a sample of the chopped corn was taken as it was packed in the silos and the silage was sampled at intervals up to 84 days. At the end of 60 days the silage was fed daily to dairy cows with 3 animals per insecticide level and control.

After 28 days storage residues were 1.37, 3.61 and 9.93 p.p.m., respectively, in the 4-, 8- and 16-ounce levels of dimethoate. On the 56th day the residues were 1.59, 2.80 and 5.22 p.p.m. On the 84th day when the experiment was terminated the dimethoate residues were 1.16, 2.39 and 6.10 p.p.m. indicating about one-third of the dimethoate degraded during the last 60 days of the period.

A sample of milk was obtained from each test animal a day before feeding began and then at intervals up to 28 days when the animals were placed on insecticide-free rations. On the second day traces of the dimethoate were detected in the milk of cows fed the 16-ounce level and on the 4th day in milk from those fed the 8 ounce-level and on the 7th day from those fed the 4 ounce-level of treatment. The highest residues in the milk occurred in the samples taken 21 days after exposure to the 4- and 8 ounce-levels and on the 28th day in case of the 16-ounce levels. The peak residues of dimethoate were 0.008, 0.015 and .019 p.p.m. for the 4-, 8- and 16-ounce dosages. Within 2 weeks after feeding of treated silage was discontinued, the residues of dimethoate in the milk were below the sensitivity of the analytical method.

3. Residues in silage. Laboratory tests were carried out at Tifton to study the rate of disappearance of Sevin, diazinon, dimethoate, and endosulfan from silage. About 2.5 kg of chopped green corn or oats were packed in 1-gallon jars after the addition of the insecticide at rates of 0, 4, 8, or 16 p.p.m. The jars were closed with lids having air vents and were allowed to stand at a controlled temperature. Analyses after six weeks at 120° F. showed that about one-third of the Sevin originally present was in the silage, together with traces of a degradation product, 1-naphthol. No diazinon was found. About half of the original dimethoate and three-fourths of

the endosulfan was still present after six weeks at 80° F., and from 5 to 29% of the dimethoate still remained after 7 months.

4. Residues on red clover and range grass. Analyses made at Yakima, Wash., showed that when 4 to 6 ounces of naled or diazinon per acre was applied to range grass, 85 to 100% of the residue disappeared within 3 days. On range grass treated with 4 to 16 ounces of Sevin per acre, 70 to 90% of the residue disappeared within 21 days. When 1 to 4 ounces of dimethoate per acre was applied, 80% or more of the residue was lost in 7 days. No measurable dieldrin residues were found in red clover treated with 0.8 to 1.5 pounds of aldrin per acre 66 days before harvest.

Dimethoate was applied to range grass in Montana in 1960 and 1961. The application rate was 1 and 3 ounces per acre in 1960 and 2 and 4 ounces per acre in 1961. The residue found immediately following application was 3.5 and 15.6 p.p.m. on green grass for the 1- and 3-ounce treatments, respectively, and 6.2 and 22.8 on dry grass for the 1- and 3-ounce treatments. About 90% of the residue was lost in 7 to 8 days. The residues found in 1961 were 24.0 and 68.8 p.p.m. for the 2- and 4-ounce treatments, respectively, immediately following application. From 77 to 97% of the residue was lost in 7 to 8 days.

At Yakima, Wash., analyses of range grass treated with 4 and 6 ounces of diazinon per acre carried residues of 14.0 and 25.3 p.p.m., respectively, immediately after treatment. Eighty percent or more of the residue was lost after 3 days. Range grass treated with 4, 6, 8, and 16 ounces of Sevin per acre carried residues of 34-115 p.p.m. immediately after treatment. Twenty-one days after application, from 71 to 91% of the Sevin deposit had been lost.

D. Biological Control

1. Grasshoppers. At Columbia, Mo., examination of parasitic mites from grasshoppers, indicated the presence of at least three distinct species of Eutrombidium. Basis for this separation is the shape of the posterior dorsal shield, and the configuration of the crista metopica, in addition to a characteristic setal structure and pattern in the region of the gnathosoma. In general, the mites found on Melanoplus bivittatus are characterized by an elongate and somewhat urn-shaped dorsal shield. On M. differentialis the shield is broadly oval. Mites occurring on Syrbula admirabilis have a shield which is much smaller and egg-shaped.

In rearing studies with grasshopper mites, nymphal and preimaginal pupation occurred normally. Adult mites required several weeks of 40° F. temperature to induce egg-laying. Attachment of larval mites to grasshopper hosts cannot be attempted until adults are removed from refrigeration. With new insight as to host specificity of the

mite, attachment may be accomplished and more accurate life history studies conducted.

2. Armyworms and Cutworms. For the third consecutive year, armyworm populations in 1961 remained at a low level in Louisiana. Only two small collections were obtained but the parasitism rate was 55.8%. This high rate of parasitism, which occurred after two seasons of very low host abundance, indicates that alternate hosts were available during the period of low armyworm occurrence. None of the armyworm larvae obtained this year showed evidence of bacterial or viral disease and only 2% were attacked by fungus.

At Baton Rouge armyworm moths emerging in late May and June produced no eggs. By rearing field collected larvae at 80° F., and transferring the resultant pupae to 60° for a holding period, moths were obtained which oviposited at 80° and gave rise to a generation in July. Summer rearing of this insect is therefore possible.

Thirty percent of a small collection of fall armyworms made on May 7, 1961, were parasitized. There was no disease in this collection.

3. Alfalfa Weevil. The alfalfa weevil has continued to spread in the alfalfa-growing areas in the Eastern States with many new counties reported infested in New York, Pennsylvania, Ohio, West Virginia, and Tennessee. The weevil parasites, Bathyplectes curculionis and Microctonus aethiops, have apparently become established in the near-coastal areas of New Jersey, Delaware, and Virginia, where they were released from 1958 to 1961. Tetrastichus incertus has been recovered only in the same year as the release. Dibrachoides druso and Peridesmia discus have not been recovered. In 1961, additional releases were made on two parallel lines about 275 miles apart extending westward from the Piedmont area through the mountains. A total of 21,648 specimens were released, over half of which were Bathyplectes. Others released were T. incertus, D. druso, and P. discus.

4. Spotted Alfalfa Aphid. No further releases of introduced natural enemies of the spotted alfalfa aphid were made in Arizona in 1961. One of the parasites, Aphelinus semiflavus, which was not recovered in 1960, was taken in small numbers in Yavapai and Gila Counties during the spring of 1961, at elevations of 3,000 to 3,500 feet. Another species, Praon palitans, was collected May 25, in north-central Arizona, at an elevation of about 5,000 feet, and approximately 115 miles north of the nearest release site. The known range of Trioxys utilis, a third species, widely established in central and southern Arizona by the end of 1960, was extended to Chino and Skull Valleys. No living aphids or parasitized mummies were found in a survey of alfalfa fields June 12-14 in high-elevation areas in eastern Arizona. No recoveries of introduced lady beetles and

lacewing flies were made during 1961. Between January 25 and February 23, spotted alfalfa aphids were found in 80 of 84 fields surveyed in eight Arizona counties. Aphids parasitized by T. utilis were found in 49 fields well distributed over the area. Parasitiization by this species averaged 10.4% and went as high as 50% in two fields. A. semiflavus was found in a single field in which it parasitized less than 1% of the aphids. Spotted alfalfa aphid mortality from fungus diseases was unusually low in Arizona during 1961 probably because of abnormally dry weather.

Observations on the spotted alfalfa aphid and its natural enemies and damage were continued at biweekly intervals in 1961 in four alfalfa fields near Mesa, Ariz. These fields had received little or no insecticide treatment for 5 successive years. As in 1960 the three leading predators were Collops vittatus, Orius spp., and lady beetles, in that order. The number of all predators per 100 net strokes averaged 74.6 compared with 76.8 in 1960. Predators were generally most abundant during the last half of May which was about two weeks later than in 1960. The average population of the spotted alfalfa aphid was 2.28 per leaf compared with 2.11 in 1960. Lady beetles, the most effective predators, averaged 0.13 per square foot compared with 0.06 in 1960. Average aphid mortality from fungus diseases was 0.2% in 1961 and 0.7 in 1960. Parasitization by Trioxys utilis averaged 3.8% compared with 2 in 1960. The average aphid damage was 4.7% compared with 4 in 1960. The peak periods of aphid abundance, aphid damage, and lady beetle abundance occurred from early November to mid-December in 1961 and from May to July in 1960. The fall lady beetle peak was 2 to 6 weeks later than the fall aphid peak.

Data from a 4-year period, 1958-61, in these four fields indicate that the time of the annual peak population of the aphid may occur as early as March or as late as November. In each year there were three seasonal peaks -- spring, summer, and fall -- which occurred from February to April, in July, and in October or November. In all of the years, aphid populations per leaf declined to very low levels following the spring and summer peaks. In nearly all instances a substantial increase in the aphid population was accompanied or followed by a noticeable increase in the population of lady beetles.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Grasshoppers. Several sexual attraction tests were made at Mesa, Ariz., with unmated adults of Trimerotropis p. pallidipennis. Individuals and groups of females were placed in small screen cages exposed in locations where there were sparse populations of this species. The males were not attracted by the caged females. In desert habitats the males seem to respond to the movement and location of the females, apparently sensing them by sight or by some sound that is not normally heard by the human ear. The females make little

or no sound in flight as contrasted with a fairly loud strident noise made by the males.

At Bozeman, Mont., virgin adult males and females and fifth instar males and females of the two-striped grasshopper, Melanoplus bivittatus were fed lettuce leaves treated with a 0.1% solution of ENT. 25296 (Triethylenemelamine) or ENT. 26316 (Apholate) for 4 days. No repellency was observed from either compound. However, the grasshoppers fed on ENT. 25296 became sluggish in action after one feeding and commenced dying after 3 days. At the sixth day after feeding mortality was 100%. No mortality occurred among grasshoppers fed on ENT. 26316.

2. White-fringed Beetles. At Florala, Ala., tests with chemicals for their attractiveness to white-fringed beetle adults in an olfactometer were continued in 1961. None of the 36 chemicals tested in 1961 or the 47 tested in 1960 showed any appreciable degree of attractiveness or repellency to white-fringed beetle adults.

During the summer of 1961, white-fringed beetle adults were confined in an outdoor cage, 24 by 24 feet, where they had a free choice of peanut or one other plant for food and shelter. Field-collected adults were released in the center of the cage daily and all beetles on the test plants were removed 2 or 3 times each day. Beetles showed a decided preference for peanut over corn, cotton, cocklebur, soybean, and rice, and a slight perference for peanut over sicklepod.

F. Evaluation of Equipment for Insect Detection and Control

1. White-fringed Beetles. Tests were begun at Florala, Ala., in 1960 to study the relative effectiveness of strip and broadcast application of certain insecticides against white-fringed beetles on uncultivated land. The special applicator used in these tests was provided by the Plant Pest Control Division. It applied granular formulations of insecticides in narrow bands 12 inches apart on the soil surface in such a manner that the insecticides would not come in contact with the plant foliage. The plots were treated and infested with egg masses in October 1960 and larval populations were determined in April 1961. Aldrin, chlordane, dieldrin, heptachlor, and Sevin were each used at 2 or 3 rates. Sevin was not effective as a surface treatment. The broadcast applications gave better control than the strip applications. The machine disturbed the surface of the soil, thereby enabling the newly hatched larvae to penetrate the soil more readily. This factor caused a greater survival in all plots treated with the machine than in the plots receiving broadcast applications. In plots which received no insecticide, the soil disturbance from the machine caused a 91% increase in larval survival over that which occurred in untreated nondisturbed plots.

G. Varietal Evaluation for Insect Resistance

1. Spotted Alfalfa Aphid. The polycross progenies of experimental combination SW-1 (27 superior clones from Arizona, California, and Nevada) were evaluated for spotted alfalfa aphid resistance in Arizona and California. At Mesa, Ariz., seedlings, exposed in a lath house to four infestations of aphids from June 12 to 21, showed mortalities ranging from 34.5 to 81.1%. At Bakersfield, Calif., seedlings were exposed to infestations of biotype ENT B and biotype ENT A. Biotype B caused mortalities ranging from 3 to 27.5% and biotype A 1.5 to 28.5%. The 10 entries having lowest mean mortalities at Mesa were Y-5-10, Y-5-41, E-5, M-5-20, N-1173, C-906, Y-5-8, M-5-44, N-2054, and E-10. Four of these were among the best 10 at Bakersfield in both the test with ENT B and ENT A. Only one entry, N-1173, was in the first 10 in all three tests.

Twelve 2-clone combinations were tested at Mesa for resistance to the spotted alfalfa aphid. A high percentage of the progenies of several of the hybrids was highly resistant. In reciprocal crosses, the greater number of resistant plants was obtained when the more resistant clone was used as the female parent. Twenty-five promising clones of Chilean 21-5 selected for possible use in developing a resistant Chilean-type variety were tested for antibiosis to the spotted alfalfa aphid. One of these clones was selected at Yuma, and the other 24 came from an abandoned alfalfa field near Arlington. Two clones were classed as highly resistant, and two as intermediate.

At Bakersfield 1,004 stem-cage tests were made to evaluate spotted alfalfa aphid resistance in clones submitted by California and Nevada plant breeders. Most of them were given two adult tests instead of the longer nymph test. For the most part results from the duplicate tests were similar. However, cool weather tests did not always adequately agree with hot weather tests. The more resistant the clone, the better was the agreement between tests. In cool weather it was difficult to distinguish intermediate plants from susceptible plants and some of the variation between tests could be charged to the changing of reaction in mid-summer and a highly susceptible reaction in October or November.

In Arizona counts of the spotted alfalfa aphid were made each month in four fields planted to aphid-resistant Moapa alfalfa and four to aphid susceptible African or Chilean. The aphid population averaged 8.3% as high in Moapa as in the susceptible varieties. Estimated aphid damage to alfalfa foliage averaged 0.13% in Moapa fields as compared with 3.04% in fields of the susceptible varieties. These results are similar to those obtained in 1959 and 1960.

Additional recoveries of biotype ENT A were made in the field in 1961 and 1962. Aphids collected at El Centro, Calif., in February

1961, from damaged and undamaged Moapa were tested on clone 903 and 10% of them proved to be ENT A. The first recovery of ENT A outside of the Imperial Valley was made in a Moapa field near Bakersfield, Calif., where about 1% of the aphids collected belonged to this biotype. On June 11, 1962, a collection of aphids from an alfalfa planting to produce seed of experimental variety SW-5 at Marana, Ariz., were almost pure biotype ENT A. This is the first record of this biotype outside of California.

2. Pea Aphid and Leafhoppers. Three experimental combinations (SW-1, SW-2, SW-5) of alfalfa clones having resistance to the spotted alfalfa aphid and high yield potential were evaluated at Mesa, Ariz., for tolerance to the pea aphid. Several clones are common to all three combinations and two of them (N-2038 and Y-5-7), which showed considerable promise in previous tests, were again among the lowest in pea aphid population.

At Lincoln, Nebr., research is underway to develop combined resistance in one alfalfa variety to the spotted alfalfa aphid, the pea aphid and the potato leafhopper. Forty-three clones from a group selected from plant introduction seedlings after a heavy infestation of pea aphids were tested for antibiosis to the spotted alfalfa aphid. None of the 8 showing resistance to the spotted alfalfa aphid showed antibiosis resistance to the pea aphid. Thirty-four clones selected from parents having resistance to the spotted alfalfa aphid and from polycross progenies of C clones were tested. Of these, 8 were resistant, 4 intermediate and 22 susceptible to the pea aphid. Twenty clones selected for apparent resistance to the pea aphid from mass screening tests of polycross or open-pollinated progeny of spotted alfalfa aphid resistant clones were tested for antibiosis resistance to the pea aphid. Nine were resistant, 4 intermediate, and 7 susceptible. Separate genes are involved in resistance to the two aphids and seedlings selected for resistance to one aphid are not necessarily resistant to the other.

Thirty-one of 41 clones that showed pea aphid resistance in the seedling stage showed resistance as mature clones. Seven of these were resistant to the spotted alfalfa aphid.

In a test at Lincoln with open pollinated and synthetic clones several of the open-pollinated and the synthetics E-10 (Arizona), KS6 Syn. 1 (Kansas), Nevada Syn. T, and Nebraska Syn. 27 and 28, were resistant to both aphids.

Selections from Nebraska synthetic 24, Syn-2, which showed apparent potato leafhopper resistance were tested for antibiosis resistance to the spotted alfalfa aphid. Five were resistant, six intermediate and 33 susceptible.

3. Alfalfa Weevil. All alfalfa material in field nurseries at Beltsville, Md., was rated for resistance to the alfalfa weevil. Large differences in larval damage occurred among entries. Greenhouse studies with selections of the same material using larval and adult feeding tests have so far failed to correlate with field damage ratings. Field differences may be due to adult preference for oviposition.

4. Alfalfa Seed Chalcid. The evaluation of alfalfa seed chalcid resistance in Lahontan, Sirsa #9, and different species of Medicago at Mesa, Ariz., gave further indication that clone C-89 contributes most of the resistance present in Lahontan. Sixteen plants from Lahontan having low chalcid infestations were selected for further study from 125 plants tested. Also selected as promising were two of 61 Sirsa #9 plants tested. From progenies of two clones previously selected from Sirsa #9 for chalcid and spotted alfalfa aphid resistance, 10 additional chalcid-resistant plants were selected. Studies on the different species of Medicago were only partially successful. Fifty-five of 132 entries tested were fully evaluated. Twenty-two other entries were partially evaluated, but seed produced on the remaining 55 entries was insufficient for study. Most of the entries were dormant types, and injurious insects other than the chalcid were very numerous and probably contributed to poor seed set. There were highly significant differences among the fully evaluated entries. The species having the lowest chalcid population was M. argopyrethrum, a nondormant species.

5. Lygus Bugs. Evaluation of 80 varieties of alfalfa at Mesa, Ariz., for resistance to lygus bugs during a 2-year period indicated that the variety Zia, which has spotted alfalfa aphid resistance, showed considerable promise for resistance to lygus bugs.

6. Sweetclover Aphid. Selections studies at Lincoln, Nebr., on the inheritance of resistance to the sweetclover aphid in yellow-flowered sweetclover (Melilotus officinalis) indicate that resistance is dominant over susceptibility and is governed by a single gene pair. This was determined by the evaluation of 913 F_2 seedlings from 11 F_1 lines of a resistant x susceptible cross and its reciprocal and the evaluation of about 250 backcross plants. Crosses with other selections suggest that a factor may be present which modifies resistance. White-flowered selections (M. alba) were not studied as intensively but there is good indication that in this species sweetclover aphid resistance is also governed by a single pair of genes.

On susceptible sweetclover selections the nymphal developmental period of the sweetclover aphid varied from less than 6 days at 85° F. to more than 20 days at 55°. No aphid development was completed on one resistant selection while on another no development occurred

at 85° and very little at lower temperatures. Where the nymphal development was completed on resistant plants the time required was not different from that on susceptible plants.

H. Insect Vectors of Diseases

1. Vectors of Mosaic on Yellow Lupine. Research is underway at Tifton, Ga., to develop methods of controlling aphids that are vectors of bean yellow mosaic virus of yellow lupine. Phorate, dimethoate and Di-syston were applied to entire fields at the rate of 2 pounds per acre in an 8-inch band over rows of 2- to 4-inch high seedling plants and again approximately 30 days later. The average aphid populations per 10-raceme sample for eight sampling periods for the treatments were: Dimethoate 6, phorate 10, Di-syston 22, and the untreated control 43. The most effective of the applications on control of the virus as determined from virus counts of 1500 plants per field after seed set were in percent of plants showing virus symptoms, dimethoate 13, phorate 23, Di-syston 33, and the untreated control 81.

2. Vectors of Red Clover Root Rots. At University Park, Pa., studies were made to determine whether the control of root weevils and root rots would increase the longevity of red clover stands. Plots were sprayed periodically with insecticides and fungicides singly and in combination during the seedling and first crop year. At the end of the second year, the percent of ground cover for check plots averaged 19; fungicide plots 24; insecticide plots 48; and combined fungicide-insecticide plots 63.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Blickenstaff, C. C. 1962. Failure of the grasshoppers Melanoplus bilituratus and M. confusus to cross-mate in confinement. Jour. Econ. Ent. 55(3):421.

Dennis, R. E., Nielson, M. W. et al. 1961. Alfalfa for forage production in Arizona. Ariz. Agr. Expt. Sta. Bul. A-16. 36 pp.

Howe, W. L. and Manglitz, G. R. 1961. Observations on the clover seed chalcid as a pest of alfalfa seed in Eastern Nebraska. Proc. N. Cent. Br. E.S.A. 16:49-51.

Lieberman, F. V., Dicke, F. F. and Hills, Orin A. 1961. Some insect pests of important seed crops. Yearbook of Agriculture. pp. 251-258.

Manglitz, G. R., Bergman, P. W., Howe, W. L., and Calkins, C. O. 1962. Overwintering in the egg stage by the spotted alfalfa aphid in Nebraska. Jour. Econ. Ent. 55(3):292-294.

Nerney, N. J. 1961. Effects of seasonal rainfall on range condition and grasshopper populations, San Carlos Apache Indian Reservation, Arizona. Jour. Econ. Ent. 54(2):382-385.
Nielson, M. W. and Barnes, O. L. 1961. Population studies of the spotted alfalfa aphid in Arizona in relation to temperature and rainfall. Ann. Ent. Soc. Amer. 54(3):441-448.
Nielson, M. W. and Bleak, E. E. 1961. An apparatus for collecting and separating live insects. Jour. Econ. Ent. 54(4):801-802.
Prescott, H. W. and Anderson, W. H. 1961. Characters for separating larvae of Sitona lineata (L.) and Sitona hispidula (F.) (Coleoptera: curculionidae). Ann. Ent. Soc. Amer. 54(3):465-466.

Insecticidal and Cultural Control

Roth, V. D. 1962. Germination of alfalfa seed treated with dry and liquid formulations of Di-syston and phorate. Jour. Econ. Ent. 55(1):1-2.
Skoog, F. E., Cowan, F. T., and Connin, R. V. 1961. Laboratory and field tests of new insecticides for grasshopper control. Jour. Econ. Ent. 54(1):170-174.

Insecticide Residue Determinations

Fahey, Jack E., and Blickenstaff, C. C. 1960. Residues of Diazinon, Guthion, heptachlor and Sevin on mixed pasture grass. Proc. N. Cent. Br. E.S.A. 15:33-35.
Fahey, Jack E., Wilson, M. Curtis, and Rusk, Harold W. 1960. Persistence of BHC, lindane and Thiodan residues when applied to alfalfa to control the meadow spittlebug. Jour. Econ. Ent. 53(5): 960-961.
Osburn, Max R., Dawsey, L. H. and Woodham, D. L. 1960. Insecticide residues on forage under sprayed pecan trees. Jour. Econ. Ent. 53(5):719-721.
Westlake, W. E. and San Antonio, J. P. 1960. Insecticide residues in plants, animals and soils. ARS 20-9:105-115.

Biological Control

Prescott, H. W. 1961. Respiratory pore construction by the Nemestrinid parasite, Neorhynchocephalus sackenii (Will.), Diptera, with notes on respiratory tube characters. Ann. Ent. Soc. Amer. 54(4):557-566.
Raun, Earle S. 1961. The place of biological control in forage crop production. Proc. N. Cent. Br. E.S.A. 16:55-56.

Varietal Evaluation for Insect Control

Manglitz, G. R. 1961. Insects and sweetclover seedlings. Nebr. Expt. Sta. Qtrly. 7(4):23.
Manglitz, G. R. and Gorz, H. J. 1961. Resistance in sweetclover to the sweetclover aphid. Jour. Econ. Ent. 54(6):1156-1160.

AREA 6. SOYBEAN AND PEANUT INSECTS

Problem: Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. In the absence of specific support for research on soybean insects, some shifts in emphasis have been made to investigate some of the problems. However, basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resistant crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA PROGRAM

The Department has a limited program involving basic and applied research on the insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations.

The Federal scientific effort devoted to research in this area totals 1.5 professional man-years. Of this number 0.4 man-year is devoted to basic biology, physiology, and nutrition; 0.5 to insecticidal and cultural control; 0.5 to insecticide residue determinations; and 0.1 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 3.0 professional man-years divided among subheadings as follows: Basic biology, physiology and nutrition 0.6, insecticidal and cultural control 1.8,

insecticide residues 0.4, and varietal evaluation for insect resistance 0.2. State stations are studying the biology of stink bugs, armyworms, and the grape colaspis on soybeans and means to control these pests. In the Virginia-North Carolina peanut area, State stations are conducting research with new insecticides for rootworm control on peanuts, because this insect has developed resistance to formerly effective insecticides, and on residues in peanut kernels and hay. Selection and testing of peanut varieties for rootworm resistance are also underway.

Industry and other organizations contribute to the research effort on soybean and peanut insects. Chemical companies make significant contributions on synthesis, analysis, formulation, and primary screening of insecticides, which are discussed in another area, and conduct limited field testing of insecticides against insect pests of soybeans and peanuts. Soybean and peanut producers supply fields of soybeans or peanuts in which tests may be conducted. Estimated annual expenditures of industry, exclusive of grants and cooperative agreements to State or Federal stations, are equivalent to approximately 1 professional man-year.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Soybean Insects. In screen-cage tests at Columbia, Mo., during 1961, the period of maximum damage to soybeans by the brown stink bug Euchistus servus occurred during the four-week period following bloom. Most damage took place in the last half of this period and declined noticeably thereafter. The total number and weight of beans, and the number of pods produced, were not significantly different for three 2-week infestation periods following bloom. Most of the damage occurred in the lower third of the plants and significant differences due to time of infestation were confined almost exclusively to this area.

To evaluate damage to soybeans in relation to various densities of brown stink bug infestation, screen cages were placed in field plots and infested with one, two, three, and four pairs of the insect. The number of immature or underdeveloped soybeans was significantly higher than the check at all rates of infestation. The immature seeds from the middle third of the plants showed significant differences from the check plots as well as between the treatments themselves, except between treatments consisting of 2 and 3 pairs of insects per cage. Stink bugs confined in cages containing six soybean plants damaged approximately 5 seeds per plant per bug. The germination of soybean seeds was reduced in relation to the number of stink bug punctures per bean. Beans from check plots

showed 98-99% germination while those receiving 1, 2, 4 and 8 or more stink bug punctures per bean germinated at 93, 91, 81, and 37%, respectively.

Determination of oil and protein content of five commercial varieties of soybeans damaged principally by the green stink bug, Acrosternum hilare, revealed a decrease in oil content and an increase in protein content. It is believed that this condition is directly related to the size of the bean rather than to any significant tissue damage. As seed size decreases the amount of seed coat tissue increases in proportion to the oil bearing endosperm. Thus, stink bugs may indirectly affect oil and protein content by causing the production of smaller seeds.

B. Insecticidal and Cultural Control

1. Soybean Insects. Stink bug damage to five commercial varieties of soybeans grown at Columbia, Mo., decreased as the planting dates became later after April 19. Considerable variation in damage was observed between varieties within planting dates but all damage from stink bugs was reduced as planting dates were extended through May into mid-June.

At Tifton, Ga., Sevin, Guthion, diazinon, endosulfan and dimethoate were applied to soybeans at 1 pound per acre when the pods were small and the plants still blooming to determine control of the velvet bean caterpillar, the fall armyworm and the Mexican bean beetle. Insect populations were light but in all treatments they were lower than in the check. Differences were not significant, however, except for the velvet bean caterpillar and the Mexican bean beetle in the counts taken two weeks after application. Endosulfan gave best control of the velvet bean caterpillar, followed by Guthion, Sevin, dimethoate and diazinon. Dimethoate gave best control of the Mexican bean beetle, followed by endosulfan, Sevin, Guthion and diazinon. Since an infestation of the fall armyworm did not develop in the test area, 4-day old laboratory-reared larvae were fed 1-inch leaf discs from the treated plots. While all materials caused mortality of the larvae, diazinon, Guthion and Sevin were the most promising.

C. Insecticide Residue Determinations

1. Soybean Insects. At Tifton, Ga., dimethoate was applied at 4, 8 and 16 ounces per acre in an emulsion spray to soybean foliage suitable for harvesting as hay. Plant samples taken 1 day after treatment showed residues of 5.86, 7.06, and 7.96 p.p.m. for the 4-, 8- and 16-ounce treatments, respectively. On the 8th day after treatment the residues were .026, .052 and .110 p.p.m.

2. Peanuts. Peanuts were grown at Tifton in soil treated with broadcast and row-band applications of aldrin at 1-1/3 pounds per acre and heptachlor at 2 pounds per acre in 1960. Soil residues from the two types of treatment, respectively, at harvest, 4 months after planting, were 0.10 and 0.16 p.p.m. heptachlor; .06 and .03 p.p.m. heptachlor epoxide; 0.20 and 0.31 p.p.m. aldrin; and 0.14 and 0.24 dieldrin. Residues of heptachlor (0.15 and .04 p.p.m.), heptachlor epoxide (0.10 and .02 p.p.m.), aldrin (.02 and .02 p.p.m.) and dieldrin (0.36 and 0.17 p.p.m.), were found on the vines at harvest. Peanut hulls showed .06 and 0.20 p.p.m. heptahclor, 0.18 and 0.38 p.p.m. heptachlor epoxide, .01 and 0.10 p.p.m. aldrin and 0.33 and 1.70 p.p.m. dieldrin. The peanut meats contained residues of heptachlor (.08 and 0.38 p.p.m.) and heptachlor epoxide (0.68 and 1.34 p.p.m.) from the heptachlor treatment, and aldrin (0 and 0.11 p.p.m.) and dieldrin (0.72 and 1.91 p.p.m.) from the aldrin treatment. In 1961 peanuts were planted on the same soil and harvested in October, 17 months after the insecticide treatment. Residues of aldrin plus dieldrin on the whole unwashed nuts were 0.11 and 0.13 p.p.m., and of heptachlor plus heptachlor epoxide, .07 and .02 p.p.m., for the broadcast and row band treatments, respectively.

These data indicate that soil treatments of granular aldrin and heptachlor at rates of 1-1/3 to 2 pounds per acre when made at planting time will result in residues on the forage, peanuts, and in the meats at harvesttime.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

None.

AREA 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghums, and small grains. In 1960 it was estimated that the European corn borer alone destroyed corn worth more than $96 million. A recently expanded research program will permit an intensification of research on many of the problems associated with these insects. This program calls for research to provide more efficient insecticides that can be safely applied to the crops, that do not harm animals consuming the feed, or leave excessive residues in meat and milk. Improved cultural methods of control will be investigated, and the factors influencing insect abundance will be studied to provide current information that can be used to advise growers of the need for insect control. New approaches to control, such as sterilization techniques and sex attractants, will be explored. More attention will be given to biological-control methods such as the use of parasites, predators, and diseases. Research on varietal resistance to insects in corn, sorghums, and small grains will be intensified in cooperation with plant breeders and the nature and inheritance of such resistance determined.

USDA PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on hessian fly and wheat jointworm at West Lafayette, Ind., and Manhattan, Kans.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. D., and Tifton, Ga.; wheat stem sawfly at Minot, N. D., Brookings, S. D., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and West Lafayette, Ind.; fall armyworm, pink scavenger caterpillar and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. D., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. D.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and the insect transmission of grain diseases at Manhattan, Kans., and Brookings, S.D. Research to evaluate improved equipment for

application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. The station at Denton, Tex., concerned with studies of the resistance of small grains to greenbug was closed in September 1961, and the manpower and funds transferred to Stillwater, Okla., to provide for needed research on sorghum insects, in cooperation with the Oklahoma Experiment Station.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" with the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland, was activated in January 1961. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" with the Hebrew University, Rehovoth, Israel, was activated in February 1962.

The Federal scientific effort devoted to research in this area totals 37.8 professional man-years. Of this number 9.5 is devoted to basic biology, physiology, and nutrition; 4.6 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.0 to biological control; 2.3 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 11.9 to varietal evaluation for insect resistance; 1.6 to insect vectors of diseases; and 1.4 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 27.1 professional man-years divided among subheadings as follows: basic biology, physiology, and nutrition 10.3, insecticidal and cultural control 9.0, insecticide residues .6, biological control 1.4, insect sterility, attractants, and other new approaches to control .2, evaluation of equipment for insect detection and control .7, varietal evaluation for insect resistance 3.5, and insect vectors of diseases 1.7. Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and South Dakota are conducting cooperative studies under Regional Project NC-20 on factors influencing European corn borer populations. The biology, ecology, and systematic relationship of the complex of corn rootworms in the Corn Belt is being worked on to clarify confusion in species and habits. Insecticides are being tested for control of the more important grain insects. A limited amount of work is underway on the use of bacteria and fungi as natural control agents for grain insects. The use of various lights as a means of attracting corn borers and earworms is being explored for detection purposes. Several State Experiment Stations have work in progress on the development of crop varieties resistant to such insects as

the European corn borer, rice weevil, greenbug and hessian fly. Transmission studies are being made to identify insect vectors of aster yellows and barley yellow-dwarf diseases of barley.

Industry and other organizations. Several chemical companies have field testing programs on insecticides for control of insect pests of corn, sorghums, and small grains. Estimated annual expenditures are equivalent to approximately 10 professional man-years. Producers of grain cooperate with the Department and State Experiment Stations in providing fields that may be used for insecticidal tests. A number of hybrid seed corn companies employ an entomologist to assist in developing corn hybrids resistant to insects. Their estimated annual expenditures are equivalent to approximately 3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. Long-range population studies on European corn borer at Ankeny, Iowa, indicated an increase of overwintering borers from 162 per acre in 1960 to over 5,000 per acre in 1962. In 1961 the first-brood population was about the same as the overwintering population, but the fall population was 5.4 times greater than that of the first brood. Resistance of corn hybrids to the corn borer was more effective in reducing first brood populations than was date of planting. However, date of planting was more effective in reducing second brood populations than was hybrid resistance.

The corn earworm caused an estimated 2.4% loss to corn in Georgia in 1961, according to studies made at Tifton, Ga. Eighty-one percent of the fields surveyed in the State were infested by rice weevil, 95% by the pink scavenger caterpillar and 30% by the fall armyworm. Damage by the corn earworm was .72% in Mississippi, 1.5 in Tennessee, 1.6 in Kentucky and .72 in Illinois in the areas surveyed. Corn earworm larvae penetrated deeper into the ears of a resistant single cross than into those of a susceptible single cross. The total number of larvae reaching the full-grown stage was greater on the susceptible cross.

At Stillwater, Okla., when corn was machine-harvested, girdling by the southwestern corn borer caused losses up to 39%, depending upon the percentage of infestation, time of planting, and environmental conditions.

2. Small Grain and Sorghum Insects. Since 1960 hessian fly infestations have decreased in wheat areas East of the Mississippi River and increased in most of the areas West of the River. The average infestation of susceptible wheat varieties in 13 Central Kansas counties was 16% whereas that of the resistant varieties was only 1%.

In biochemical studies of hessian fly larvae grown on semi-artificial media, the juices from resistant selections of wheat contained substances toxic to the larvae. The juices from susceptible varieties did not have this effect and permitted larval development. Radiological studies indicated that feeding by hessian fly larvae occurred on resistant wheats for a maximum of 2 days and on susceptible wheats for a maximum of 15 days.

In studies at Stillwater, Okla., the first and second instar larvae of the corn earworm preferred the flowering stage of sorghum kernels, and the third, fourth, fifth and sixth instar larvae preferred the milk stage. The average consumption of sorghum by corn earworm larvae under insectary conditions, in grams per instar was as follows: First instar 0.0853; second, 0.0759; third, 0.2981; fourth, 0.3533; fifth, 0.8330; and sixth, 3.1397. The average total consumption during the entire larval period was 4.7853 grams per larva.

Winter and spring varieties of wheat reacted very similarly to wheat curl mite development at Manhattan, Kans., when the winter wheat was vernalized or when light and temperature conditions were such that the fruiting growth of spring wheat was delayed or suppressed. Mites reproduced very rapidly on the vegetative stages of both winter and spring wheats, but their numbers declined as the plants began to send up fruiting clums. This decline continued until just prior to maturity when there was a short period of very rapid mite reproduction.

Studies on the leafhopper Calligypona pellucida in Finland under P.L. 480 project E8-ENT-1 disclosed that the insect overwinters in timothy fields and migrates, largely as winged adults, to grain fields in June. The migrations were principally to oats and spring wheat. The most important natural enemies of the leafhopper were two species of Hymenoptera which destroyed large numbers of eggs. About 0.7% of the nymphs and 20.0% of the adults were parasitized by other species of Hymenoptera. Fall plowing also destroyed large numbers of nymphs.

B. Insecticidal and Cultural Control

1. Corn Insects. In field tests one application of Telodrin (SD-4402) at .2 pound per acre applied in granules or a spray gave satisfactory control of the European corn borer at Ankeny, Iowa. For second brood corn borer control, 25 pounds per acre of 1% endrin granules gave better control than 6.25 pounds of 4% endrin granules, and granules of 40/50 mesh size gave better control than granules of other sizes.

Thirteen insecticides were tested for control of the earworm at State College, Miss. Bayer 44646 alone gave control equal to DDT and Sevin. Tung oil did not increase control when added to sprays containing DDT or Sevin.

Three applications of endrin at 2 pounds per acre and of Sevin at 1.5 pounds reduced southwestern corn borer infestations from 52.8 to 4.8 and 8.0%, respectively. DDT at 2 pounds per acre failed to reduce the infestation.

Effective control for the lesser cornstalk borer on sorghum and corn in Mississippi was obtained by applying phorate granules at the rate of one pound of phorate per acre, or aldrin as a spray or granules at one or two pounds of aldrin per acre, in an 8-10 inch band along the drill row at time of planting.

2. Small Grain and Sorghum Insects. A search for more effective insecticides and better methods of applying them for wheat stem sawfly control has been continued at Minot, N. Dak. The best control obtained in 1961 was 51% with heptachlor as a furrow application at 1 pound per acre.

At Stillwater, Okla., the influence of low temperatures on effectiveness of insecticides for controlling the greenbug was studied at temperatures of 35-60° F. The organic phosphates tested gave good initial control throughout this range of temperatures, but Phosdrin gave poor residual effectiveness at temperatures above 60° F.

The application of nitrogen to wheat, in addition to increasing plant growth, usually caused an increase in the population of apple grain aphids and English grain aphids. However, the type of formulation of nitrogen and time of application had some effect on plant growth and aphid population. Ammonia nitrate applied both in spray and solid form in the spring produced the least plant growth and lowest aphid populations. Fall application resulted in the largest plants and highest aphid populations. Cultural practices of wheat such as stubble mulching and crop rotation had no apparent effect on populations of aphids which moved into the crop after the plants emerged.

C. Insecticide Residue Determinations

1. Residues on Corn. Kernels from corn in plots treated with Dylox, diazinon, Sevin, and heptachlor epoxide contained no residue in detectable amounts in samples collected 1 day after treatment. EPN was applied at .5 pound per acre within 7 days of harvest to corn without leaving more than 0.2 p.p.m. residue on the stalks.

When Telodrin (SD-4402) was applied to dent corn at 0.1 pound per acre for first-generation corn borer control, the residues were less than 0.5 p.p.m., 68 days after treatment. When the dosage was increased to 0.2 pound of Telodrin per acre, the residues 5 days after treatment averaged 1.2 p.p.m. and declined to 0.6 p.p.m. or less 59 days after treatment. Granular applications of the insecticide applied for second-generation borer control left residues of

1.0 p.p.m. from a 0.1 pound-per-acre dosage and 0.8 p.p.m. from a 0.2 pound-per-acre dosage 43 days after application.

Spray and granular EPN were applied at 0.25 pound per acre to corn plots on July 6 and 11. Parathion spray and granules were applied to other plots at 0.5 pound of parathion per acre. Husk-cob (silage) samples taken at intervals were analyzed at Vincennes, Indiana, when fresh and after fermentation. With EPN the fermented samples averaged about 0.1 p.p.m. higher in residue than unfermented samples, whereas the opposite was true with parathion. The corn stalks carried greater residues of both EPN and parathion than the other plant parts. Sprays deposited greater residues of both EPN and parathion on corn plants than did granules. Corn kernels contained no more than 0.1 p.p.m. of either parathion or EPN, even when samples were collected 1 day after treatment.

Residues in corn resulting from treatment with several insecticides were investigated at Vincennes. In plots treated with 0.25 pound of endrin per acre as a spray or granules, the greatest amount of residue was retained by the stalks of the corn plants, which contained as much as 0.15 p.p.m. of endrin 38 days after treatment. The husk-cob waste from these plots contained 0.1 to 0.5 p.p.m. of endrin 1 to 7 days after treatment and less than 0.1 p.p.m. 38 days after treatment. The corn kernels were free of endrin.

In another study, EPN was applied to corn at 0.5 pound per acre in granular form to determine the rate of loss of residue from the plants and to see whether the EPN would undergo any decomposition in the fermentation of corn silage. Applications were made on July 12 and 20. Samples of the plants collected at intervals were chopped, mixed, and aliquots taken for analysis and for sealing in polyethylene bags to ferment. Immediately after treatment the plants contained 5.5 to 7.8 p.p.m. of EPN. After fermentation the residues decreased to 3.2 to 5.9 p.p.m. EPN was lost rapidly from the plants, dropping to about 0.1 p.p.m. in one week. Silage made from corn cut one week after treatment contained 0.1 to 0.2 p.p.m. of EPN.

Analysis of corn plants treated from 1 to 4 times with endosulfan (Thiodan) spray or granules at 1 pound per acre showed the greatest residue on the stalk, about 5 p.p.m. of endosulfan, one day after spraying and 1.5 p.p.m. after the granular treatment. Husk and cob contained about 0.8 p.p.m.; no residue was found in the kernels. Delnav residues on corn plants from a single spray of 1 pound per acre averaged 9.2 p.p.m. 24 hours after application. In plots treated 3 times with Sevin at the rate of 1 pound per acre as spray or granules, corn sampled 7 days after the last application had 0.4 p.p.m. of Sevin in the stalks from the granular treatment and none from the spray. The husk and cob contained about 0.3 p.p.m. of Sevin and the kernels none.

Granular formulations of diazinor, Sevin, or phorate were applied to field corn at rates of 1 and 2 pounds of toxicant per acre. Less than 0.1 p.p.m. of diazinon remained in the corn plants 58 days after treatment. Sevin residues were 3.2 and 7.7 p.p.m. five days after treatment with the 1 and 2 pound dosages, respectively. Ninety days later the Sevin residues were less than 0.1 p.p.m. Phorate residues about 2 months after treatment were less than 0.1 p.p.m. for the 1-pound dosage and about 0.1 p.p.m. for the 2-pound dosage. Granular formulations containing 5% and 20% BHC were applied to corn at 1 pound of BHC per acre. The residues 5 days later averaged 1.21 p.p.m. of BHC from the 20% formulation and 3.57 p.p.m. from the 5% formulation. The difference is attributed to the greater bulk of the formulation containing 5% BHC.

Residues in corn plants resulting from application of Dylox granules and Dylox sprays were estimated from the organic phosphorus residues present in the plants. When granules were applied at the rate of 1 pound of Dylox per acre, the residues averaged 1.1 p.p.m. of Dylox 6 days after treatment and 0.1 p.p.m. about 2-months after treatment.

2. Residues on Wheat. Granular heptachlor was added to the drill row at the rates of 1/4 to 2.0 poundsof toxicant per acre when wheat was planted. No measurable heptachlor or heptachlor epoxide was found in the threshed grain from the plots receiving these treatments.

D. Biological Control

1. Corn Insects. Studies on biological control of the European corn borer were conducted at Ankeny, Iowa. Parasitism of than insect by exotic parasites increased slightly in 1961 over the previous year. Ohio, Iowa, Pennsylvania, New Jersey, and Maryland had the highest percent parasitism with 15, 14.7, 13.6, 11, and 10%, respectively. Macrocentrus gifuensis was the most important parasite in Iowa, Maryland, New Jersey, and Pennsylvania. Harogenes punctorius was recovered from 7 of the 15 States, being most abundant in Indiana and Ohio. A native parasite Labrorychus prismaticus, which emerges from the pupal stage of the borer, appeared in numbers for the first time in Iowa. A method has been developed for eliminating Perezia pyraustae in artificially-reared borers in the laboratory. This will provide a means to measure more accurately the effects of the protozoan on larval mortalities, growth and fecundity. When stress conditions are imposed on corn borer larvae infected with this protozoan, the larvae often fail to survive. Such stress conditions might be extremes of temperatures or resistant lines of corn.

Bacillus thuringiensis in granular form controlled first-brood borers as well as the standard DDT but did not control second-brood borers. When applied to the upper parts of corn plants as a spray the bacteria gave poorer control of the fall armyworm than DDT or Sevin, but gave almost as good control as Sevin when the spray was forced deeply into the whorls.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. At Ankeny, Iowa, a study evaluating the use of X-rays in the sterilization of corn borer moths showed (1) exposures of 1-day old male moths to 32,000 roentgens resulted in 1% hatch in eggs laid by untreated females mated with the treated males and (2) exposure of pupae to X-rays resulted in a reduction in the percent of egg hatch as the dose increased. Chemicals extracted from female moths of the European corn borer were not attractive to the males.

2. Small Grain Insects. Ethanol extracts of hessian fly female adults attracted male adults whereas water extracts had no effect in work at West Lafayette, Ind. Tests designed to determine if an olfactory sex attractant was involved in the sawfly mating process were negative.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. Since granular formulations vary in density, it has been difficult to make easy calibrations of the discharge rate from granular applicators. Cooperation has been given the agricultural engineers at Ankeny, Iowa, in their development of a simple apparatus whereby correction factors for different densities can be compensated for and the pounds of granules per acre for a specified row width can be determined directly from a scale.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. Investigations on strains of corn resistant to the European corn borer continued at Ankeny, Iowa, and Wooster, Ohio. A program to improve the inbred line WF 9 for resistance to first-brood infestation of the corn borer and at the same time retain its highly desirable qualities as a seedparent, has been underway since 1950. A group of WF 9 recovered lines produced by recurrent selection procedures continue to show a very satisfactory level of resistance to leaf feeding of first-brood borers. Several resistant lines developed during the past 10 years have been given permanent Iowa B designations. Permanent designations have also been assigned to five lines which originated in the cooperative USDA-Ohio corn resistance program at Toledo and Wooster, Ohio. Oh 501 was derived from (W24 X B2); Oh 502 and Oh 503 are sister

lines derived from an Ohio 24-line synthetic variety; and Oh 504 and Oh 505 are AF 9 recoveries derived from (41.2504 B x WF 9)s. These lines have indicated a good degree of resistance to corn borer, leaf blight, and stalk rot.

Genes that induce mutation are being utilized to induce borer resistance in four corn borer susceptible lines (WF 9, Oh 07, Oh 04, and Oh 28) which have superior agronomic characteristics. Several hundred Oh 28-mutable system plants from these tests had a low level of larval establishment from an artificial infestation.

Experimental dent corn hybrids and crosses, and commercial hybrids, were evaluated for corn earworm resistance in Georgia, Mississippi, Louisiana and Texas. Some of the consistently better corn earworm resistant hybrids are Miss. 6133, Miss. 6131, Pfister 653W, Coker 71, and Dixie 18. Single-cross and three-way cross tests show that inbreds L501, L503, F44 and F6 are good sources of earworm resistant germ plasm. Resistance, especially in L501 and L503, is dominant in the single cross progenies.

No outstanding resistance was observed in dent corn to the pink scavenger caterpillar or rice weevil but there was some evidence that a long, tight husk reduced the damage caused by these insects.

2. Small Grain and Sorghum Insects. Cooperative research with wheat breeders in several States was continued to develop hessian fly resistant wheats under leadership at West Lafayette, Ind. Fifteen fly resistant varieties are now recommended or grown in 31 States. The fly-resistant wheats, Ace, Georgia 1123, and Lathrop were released by Arkansas, Georgia and Wisconsin, respectively, in 1961. Ace and Georgia 1123 have the W38 resistance; and Lathrop, a spring wheat, carries the P.I. 94587 resistance. Many other selections in the wheat breeding program in Kansas, Indiana and other States have a high degree of resistance to one or more hessian fly races.

In a continuation of monsomic studies to locate the chromosomes responsible for the W38, P.I. 94587 and Ribeiro resistance to hessian fly, chromosome IC was tentatively identified as responsible for the single gene resistance of a Purdue P.I. 94587 derivative.

Thirty-two Purdue barley selections having the Nile and Delta resistance reacted resistant or heterozygous to Races A and D of the hessian fly. F_1 crosses between six resistant barleys were made to determine if they differed from one another genetically in respect to fly resistance. The Besert and Decatur backcrosses reacted resistant when based on plant reactions. When based only on the absence of viable larvae regardless of plant reaction, many of the lines were resistant.

Studies on wheat stem sawfly resistance were conducted at Minot, N. Dak., and Bozeman, Mont., in cooperation with wheat breeders of the Cereal Crops Research Branch, Crops Research Division, and entomologists and plant breeders of the North Dakota and Montana Agricultural Experiment Stations and the Science Service Laboratories of the Canada Department of Agriculture.

In the International sawfly nurseries several selections were more resistant than the Rescue check. Sawtana (Rescue x 1831, B51-9), a product of the breeding program in Montana, has good sawfly-resistance and agronomic qualifications and was released as a commercial variety to Montana growers in 1961. Another, II-50-17 x51-2688, 57-134, from the North Dakota program, has good resistance to sawfly, leaf and stem rust. It also has good agronomic characteristics as well as good milling and baking quality, and is being considered for release.

Studies on the development of greenbug-resistant varieties of wheat have been in progress for several years at Stillwater, Okla. The resistant Dickinson Sel. 28-A has been crossed successfully with Ponca, a high quality wheat, and many desirable agronomic characteristics have been transferred to the selections while maintaining a high degree of greenbug resistance. When some F_7 selections of the cross were compared with Ponca under heavy greenbug infestations, about 2/3 of the Ponca plants were killed and the yield was only 1.4 bushels per acre. None of the plants of the greenbug-resistant F_7 selections were killed and yields ranged from 12.1 to 17.7 bushels per acre.

Eight of 121 barley lines tested for resistance to the corn leaf aphid showed a high degree of resistance. Three of these, all Rogers x Kearney lines, are also resistant to greenbugs. Since the other corn leaf aphid resistant lines are susceptible to greenbugs, it is assumed that a different gene is responsible for resistance to the two aphids.

H. Insect Vectors of Diseases

1. Wheat Insects. Studies were continued at Manhattan, Kans., on the seasonal development of the wheat curl mite and wheat streak mosaic which it transmits, in cooperation with plant pathologists. There was a widespread infestation of the mite in most wheat fields in Kansas. However, there was little volunteer wheat and most of the population died when the crop ripened. Ten common grasses were studied in their relation to the endemic populations of the mite. Five were very susceptible to both mites and mosaic, two were susceptible to mites and not mosaic, and three although susceptible to mosaic had variable ability to sustain mite colonies. These

grasses, although important in sustaining a continuous mite population in an area, did not produce sufficient mites to cause a serious epiphytotic of the disease. The survey work of the past several years has shown conclusively that extensive early growth of volunteer wheat is necessary to cause serious spread of the disease.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Gifford, James R., Walton, R. R., and Arbuthnot, K. D. 1961. Sorghum as a host of the southwestern corn borer. Jour. Econ. Ent. 54:16-21.

Henderson, C. A. and Blanchard, R. A. 1962. The southwestern corn borer. Miss. Farm Res. Vol. 25, No. 3.

Henderson, C. F., Kinzer, H. G., Hatchett, J. H. and Wood, E. A., Jr. 1961. Sorghum insect studies in Oklahoma. Sorghum Newsletter. Vol. 4:40-44.

Jarvis, J. L., Everett, T. R., Brindley, T. A., and Dicke, F. F. 1961. Evaluating the effect of European corn borer populations on corn yield. Iowa State Jour. Sci. 36:115-132.

Lieberman, F. V., Dicke, F. F., and Hills, Orin A. 1961. Some insect pests of important seed crops. USDA Yearbook, Seeds. pp. 251-258.

Pesho, G. R. 1961. Female mating patterns and spermatophore counts in the European corn borer, Pyrausta nubilalis (Hbn.). Proc. N. Cent. Br. E.S.A. 16:43.

Wood, E. A., Jr., and Henderson, C. F. 1960. Wheat insect studies in Oklahoma. Wheat Newsletter. Vol. VIII:58.

Wood, E. A., Jr. 1961. Biological studies of a new greenbug biotype. Jour. Econ. Ent. 54(6):1171-1173.

Insecticidal and Cultural Control

Blickenstaff, C. C. and Bauman, L. F. 1961. Treated bags for control of the corn earworm and fall armyworm. Jour. Econ. Ent. 54(3): 587-591.

Brindley, T. A. 1961. Corn borer control with granular formulations. Proc. N. Cent. Br. E.S.A. 16:24.

Jackson, R. D. 1961. Use of European corn borer larvae for laboratory screening of insecticides. Proc. N. Cent. Br. E.S.A. 16:44.

Experiment Stations and Extension Services of North Central States and Ent. Res. Div., ARS cooperating. 1961. The European corn borer and its control in the North Central States. North Central Reg. Pub. No. 22. ISU Pamphlet 176.

Biological Control

Jarvis, J. L. and York, G. T. 1961. Population fluctuations of Lydella grisescens, a parasite of the European corn borer. Jour. Econ. Ent. 54:213-214.

McCoy, C. E. and Brindley, T. A. 1961. Biology of the four-spotted fungus beetle, Glischrochilus q. quadrisignatus and its effect on European corn borer populations. Jour. Econ. Ent. 54:713-717.

Raun, Earle S. 1961. Elimination of microsporidiosis in laboratory-reared European corn borers by the use of heat. Jour. Ins. Path. 3:446-448.

York, George T. 1961. Microsporidia in parasites of the European corn borer. Jour. Ins. Path. 3:101-102.

Varietal Evaluation for Insect Resistance

Chada, Harvey L., Atkins, I. M., Gardenhire, J. H. and Weibel, D. E. 1961. Greenbug resistance studies with small grains. Texas Agr. Expt. Sta. Bull. 982, 18 pp.

Gallun, R. L., Deay, H. O. and Cartwright, W. B. 1961. Four races of hessian fly selected and developed from an Indiana population. Purdue University Research Bulletin No. 732 pp. 1-8.

Gardenhire, J. H. and Chada, H. L. 1961. The inheritance of green-bug resistance in barley. Crop Science. 1:349-352.

Guthrie, W. D. and Stringfield, G. H. 1961. Use of test crosses in breeding corn for resistance to European corn borer. Jour. Econ. Ent. 54:784-787.

Guthrie, W. D. and Walter, E. V. 1961. Source of corn earworm and European corn borer resistance in experimental sweet corn inbreds. Proc. N. Cent. Br. E.S.A. 16:93.

Guthrie, W. D. and Stringfield, G. H. 1961. The recovery of genes controlling corn borer resistance in a back-crossing program. Jour. Econ. Ent. 54:267-270.

Guthrie, W. D. and Walter, E. V. 1961. Corn earworm and European corn borer resistance in sweet corn inbred lines. Jour. Econ. Ent. 54:1248-1250.

Walter, E. V. 1962. Corn earworm resistance in sweet corn inbreds released by several State Experiment Stations. ARS 33-70.

AREA 8. RICE INSECTS

Problem: A number of insects including leafhoppers, the rice stink bug, and rice water weevil, seriously damage rice in the several rice-growing areas of the United States. More information is needed on safe, effective chemical-control methods, and on cultural-control methods, to destroy these pests and reduce the damage they cause. Additional emphasis should be given to new approaches to control, such as natural sex attractants, for the rice stink bug. Rice varieties need to be evaluated for resistance to major rice insects. The discovery of hoja blanca, a virus disease of rice, and its insect vector, a planthopper, in the commercial rice-growing area of Louisiana, has greatly intensified the need for more information on the biology, ecology, and control of the vector, and on its relation to transmission of the virus.

USDA PROGRAM

The Department's program on rice insects involves entomologists, agronomists, plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station. Some of the lines of work have been underway for only a short period of time.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.3 is devoted to basic biology of leafhoppers, rice stink bug and rice water weevil; 0.2 to insecticidal control of rice stink bug and rice water weevil; 0.1 to insecticide residue determinations on rice; 0.1 to natural sex attractants for rice stink bug and other rice insects; 0.3 to varietal evaluation of rice resistance to stink bug, rice water weevil and vectors of rice diseases; 1.0 to insect vectors of hoja blanca and 0.2 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 2.7 man-years divided among subheadings as follows: Basic biology 0.7, insecticidal and cultural control 1.7, evaluation of equipment for insect detection and control 0.1, varietal evaluation for insect resistance 0.1, and insect vectors of disease 0.1. Research is conducted in Louisiana, Texas, Arkansas, and California on the above subjects as they relate to the rice water weevil, stink bug, rice leaf miner, grape colaspis and insect vectors of the hoja blanca disease of rice.

Industry. In addition to substantial contributions by industry on synthesis, analysis, formulation, and primary screening of insecticides for general use, which are discussed in another area, several chemical companies conduct limited field testing programs against rice insects. Some of them conduct field studies to determine whether harmful residues occur on the crop as a result of insecticide treatment. Estimated annual expenditures are equivalent to approximately 1 professional man-year.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Ecology, and Nutrition

1. Insect Vector of Hoja Blanca Disease. Studies were completed and much basic information obtained at Baton Rouge, La., on the general anatomy of the reproductive system of Sogata orizicola, known insect vector of hoja blanca a serious disease of rice, and of the closely related species S. furcifera and S. cubana. Mating of S. orizicola does not occur until the adults are 3 days old. Preceding copulation, the male signals the female by vibrating the abdomen and the female responds in a similar manner. After one mating, the female can lay fertile eggs throughout her lifetime. Virgin females lay an average of 56 eggs, and mated females, 161.

Cage tests conducted at Baton Rouge for the past three years indicate that the vector cannot overwinter in that area, probably due to cool weather conditions. At times during these tests, the temperature reached 18° F. Possibly the insect could overwinter farther South in the United States where minimum temperatures are more moderate.

2. Rice Water Weevil. Diapausing rice water weevils caged on rice plants in the greenhouse will feed on rice leaves. Approximately 80% of the hibernating male weevils had sperm bundles in the testes, indicating reproductive activity. None of the females examined had signs of egg development and none had been mated. The sex ratio was about 1:1. When these weevils were held for two weeks under daylight filtered through glass, supplemented with ultraviolet light, 50% of the females mated and all males were in a reproductive state. One female out of 25 had eggs. None of the group held without ultraviolet light mated. Ultraviolet light apparently stimulates reproductive activity in diapausing rice water weevils.

Several grasses, including bullgrass, dropseed, and broomsedge, and rice stubble, furnished satisfactory hibernating places for the rice water weevil. Apparently, there is a positive correlation between density of grass clumps and numbers of hibernating weevils.

B. Insecticidal and Cultural Control

1. Insect Vector of Hoja Blanca Disease. In laboratory studies with insecticides Meta-systox at 0.36 pound per acre was the most effective in controlling Sogata orizicola, the vector of hoja blanca disease. DDT and malathion at 2 and 0.5 pounds, respectively, were also satisfactory.

C. Insect Vectors of Diseases

1. Insect Vector of Hoja Blanca. Surveys conducted throughout the rice-growing area of the United States indicate that neither the disease, hoja blanca, nor its vector, Sogata orizicola is now present in the field in this country. In overwintering tests with caged insects, the vector was not able to overwinter in the rice-growing area of Louisiana.

Laboratory studies indicated that hoja blanca disease cannot be transmitted by vectors inoculated with maserated disease tissue. Attempts to transmit the disease by the mechanical infection of disease tissue directly into rice plants were also unsuccessful.

Non-infected vectors must be caged on diseased rice plants for 12 hours before they are able to transmit the virus to other rice plants. The virus must also be incubated for a period of 6 days within the gut of the insect vector before it can be successfully transmitted to rice plants.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Biology, Ecology, and Nutrition

McMillian, W. W. 1962. Investigations on the reproductive system and mating behavior of Sogata orizicola Muir. Ann. Ent. Soc. Amer. (In Press).

McMillian, W. W., McGuire, J. U., and Lamey, H. A. 1962. Hoja blanca transmission studies on rice. Jour. Econ. Ent. (In Press).

AREA 9. COTTON INSECTS

Problem. Insect control is one of the major cost factors in the production of the cotton crop. Insecticides must be utilized each year throughout the Cotton Belt for profitable production. Although a number of highly effective insecticides has been developed, the appearance of resistance to certain insecticides in 18 different cotton insect pests has emphasized the need for basic information on ways to avoid this problem and to develop other methods of control that are more effective, economical and desirable. There are some hazards involved in the currently used insecticides because of possible resulting residues in feed and food products made from cottonseed and because of drift to forage crops consumed by livestock. An imbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed. Research on sterile male techniques, attractants, arrestants, repellents, cotton varieties resistant to insects, post-season applications of insecticides to prevent diapause and winter survival, biological control agents, the development of safer chemicals, and chemical regulation of the fruiting period of the cotton plant, are among new approaches that need attention in efforts to improve current methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and of their possible eradication in all areas are needed. An outbreak of the pink bollworm in Arizona has recently posed a threat to cotton production in California. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance which can serve as a basis for advising growers when control methods for the various insects will or will not be required.

USDA Program

The Department has a continuing long-term program involving entomologists, insect and plant physiologists, pathologists, geneticists, chemists, agricultural engineers and economists engaged in both basic studies and the application of known principles to the solution of cotton growers' insect problems.

The following phases of research were terminated during the reporting period: Application of insecticide or nematode DD-136 to boll weevil hibernation sites; antibiosis as a resistance mechanism in the cotton plant to the boll weevil being conducted under an ARS contract with the Arkansas Agricultural Experiment Station; effects of the pink bollworm and other cotton insects on the quality of lint and seed; and rearing of Chelonus blackburni as a parasite of the pink bollworm.

Basic biological, physiological and nutritional studies involving (1) ecological factors affecting abundance and distribution of cotton insects in the field and laboratory are conducted at Tucson, Ariz.; Tallulah, La.; State College and Stoneville, Miss.; Florence, S. C.; and Brownsville and Waco, Tex.; (2) fundamental research in determining physiological processes, biochemical reactions and nutritional requirements in the normal metabolism of the boll weevil, bollworm, and pink bollworm are conducted at Baton Rouge, La.; State College, Miss.; Florence, S. C.; and College Station and Brownsville, Tex.; and (3) research on mode of action and fate of various chemicals in the insect, mechanisms by which insects develop resistance to insecticides and how such mechanisms may be rendered ineffective is conducted at Baton Rouge, La. The above research is cooperative with the State Experiment Stations in the respective States and with the ARS Plant Pest Control Division. Insecticidal and cultural control studies pertaining to (1) the evlauation in the laboratory of candidate chemicals for cotton insect control and field evaluation of those showing promise are conducted at Tucson, Ariz.; Tallulah, La.; State College and Stoneville, Miss.; Florence, S. C.; Brownsville, College Station and Waco, Tex.; (2) research to develop safe, economical and effective schedules of insecticide applications for guidance of growers in meeting the wide variety of insect problems on cotton is underway at Tucson, Tallulah, Stoneville, Florence, Brownsville and Waco; and (3) the effects of such cultural practices as stalk destruction, defoliation, irrigation, time of planting and soil improvement on cotton insect populations are being investigated at Brownsville and Waco, Tex. The above research is cooperative with the State Experiment Stations in the respective States. Industry cooperates extensively in this research and supplies most of the candidate chemicals. Insecticide residue determinations involving residues from the field application of various insecticides are made at State College, Miss., and Brownsville, Tex., in efforts to develop chemical control methods against cotton insects which will reduce or eliminate toxicity hazards to the public. This work is in cooperation with the Mississippi and Texas Agricultural Experiment Stations. Research on biological control agents involving (1) insect pathogens for the control of the boll weevil, pink bollworm and cabbage looper and (2) beneficial insects for the control of several cotton insects, is conducted at Brownsville, Tex.; Tucson, Ariz.; State College and Stoneville, Miss.; and Florence, S. C., in cooperation with the State Experiment Stations in these States. Fundamental research to discover and develop new methods and approaches to control cotton insects involves (1) sterile male techniques, attractants, arrestants, and repellents; (2) effects on insect development resulting from chemical manipulation of the fruiting behavior of the cotton plant by plant scientists; (3) chemical induction of plant immunity to insects into the plants; and (4) the utilization of radiant energy. This work is conducted at Tucson, Ariz.; Tallulah, La.; State College and Stoneville, Miss.; Florence, S. C.; Brownsville, College Station and Waco,

Tex., in cooperation with the State Experiment Stations in these States and with ARS Crops Research and Agricultural Engineering Research Divisions. Evaluation of equipment for insect control and detection pertaining to (1) insecticide application equipment, stalk shredders and gin and oilmill equipment for insect control and (2) light traps for detecting the presence and abundance of certain cotton insects, are made at State College and Stoneville, Miss.; and Brownsville and Waco, Tex. This work is in cooperation with the State Experiment Stations in these States and with the ARS Agricultural Engineering Research and Plant Pest Control Divisions. Varietal evaluation for insect resistance in cooperation with plant breeders is conducted at Tucson, Ariz.; State College and Stoneville, Miss.; and Brownsville, Tex., in cooperation with the State Experiment Stations in these States and the ARS Crops Research Division. Research on antibiosis as a resistance mechanism in the cotton plant to the boll weevil has been conducted under an ARS contract with the Arkansas Experiment Station.

The Federal scientific effort devoted to cotton insects research totals 58.1 professional man years. Of this number 20.2 is devoted to basic biology, physiology and nutrition; 17.8 to insecticidal and cultural control; 0.4 to insecticide residue determinations; 5.2 to biological control; 7.8 to insect sterility, attractants and other new approaches to control; 1.3 to evaluation of equipment for insect detection and control; 2.3 to varietal evaluation for insect resistance; and 3.1 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 19.7 professional man years divided among sub-headings as follows: Basic biology, physiology and nutrition, 3.8; insecticidal and cultural control, 12.3; insecticide residues, 0.1; biological control, 0.9; insect sterility, attractants and other new approaches to control, 1.1; evaluation of equipment for insect detection and control, 0.3; and variety evaluation for insect resistance, 1.2.

All of the major cotton-producing States have continuing long-term research programs involving basic and applied studies on cotton insect problems.

The work covers all of the above subjects. The Texas and Arkansas State Stations and the ARS Entomology Research Division are cooperating on research on the pink bollworm in Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm." Five Southern State Stations (Georgia, Louisiana, Alabama, Texas and Arkansas) and the Division are cooperating on boll weevil research in Regional Project S-43, "Mechanisms by Which the Boll Weevil and Other Insects Become Resistant to Insecticides."

Industry and other organizations including cotton growers also conduct research of value to cotton insect control. In addition to substantial contributions by industry on synthesis, analysis, formulation and primary screening of insecticides, which are discussed in another area, several chemical companies conduct limited insecticidal field testing programs against various cotton insects on their experimental farms or on land leased from growers. They also furnish chemicals for evaluation by State and Federal Entomologists. Cotton growers cooperate with the Department and State Experiment Stations in providing cotton fields in which insecticidal research may be conducted, and bear the cost of aerial applications of insecticides in some instances. Exclusive of contributions through grants and cooperative agreements with State and Federal Stations estimated annual expenditures of industry are equivalent to approximately 15 professional man years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Boll Weevil. Spring woods trash examinations for hibernating boll weevils in 1962 were made in Central Texas, Northeast Louisiana, the Delta and Hill sections of Mississippi and in four areas in the Carolinas. The average numbers of weevils found per acre in the springs of 1962 and 1961 in the various areas were as follows: Central Texas 1,361 and 1,516; Northeast Louisiana 2,233 and 2,193; Mississippi 1,132 and 1,246; South Central South Carolina 1,667 and 376; Coastal Plains of South Carolina and North Carolina 3,654 and 1,129; Piedmont of South Carolina and North Carolina 2,823 and 1,558; and North Central North Carolina 968 and 430. Thus in Texas, Louisiana and Mississippi the number surviving in 1962 was about the same as in 1961 while in the Carolinas it was much greater. Similar records have been made for 26 years in Madison Parish, La., and the average number found in the spring during that period was 1,346 as compared with 1,211 for 1962. In Florence, S. C., similar records have been made for 25 years with the average spring population being 2,667 weevils per acre as compared with 3,766 for 1962.

The first record of boll weevils hibernating in ground trash in the Lower Rio Grande Valley of Texas was made in the spring of 1961 when an average of 1,892 weevils per acre was found. In 1962 the average was 484 per acre. Diapausing weevils were also found in the bark surrounding palm trees, indicating that this may be an important hibernating medium for boll weevils in that area.

Evidence that the boll weevil is extending its range westward was found again during 1961. Weevils were found as far west as Cedillas in Hudspeth County, Tex., and at El Paso for the second consecutive year. No infestations were found between Cedillas and El Paso. The

farthest point in northwest Mexico where the weevil has been found was at Caborca in the State of Sonora.

An ecological survey was made in Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia and Venezuela to study the occurrence of the boll weevil, its host plant relationships, and to make observations on diapause and the severity of infestations under various cultural, climatic, and geographical conditions. The weevil was present on either cultivated and/or wild cottons in each of these countries except Panama which has no commercial cotton production.

A new malvaceous host plant, Cienfuegosia sulphurea, of the boll weevil was found in Texas. This plant is native to the Texas coast from Brownsville to Refugio. Natural infestations by the boll weevil were found at several locations in the Corpus Christi-Sinton area.

A population dynamics study in replicated field cages was conducted at Stoneville, Miss., to measure weevil population increases in terms of percentage of punctured cotton squares, effect of different populations on squaring and boll set, and to determine the level to which an overwintered population must be reduced in order to produce a crop without loss in yield or quality as a result of damage by the boll weevil. First generation weevils produced from overwintered populations, estimated at 14, 25, 50, and 100 per acre, damaged an average of 25.5, 36.5, 60.5, and 79.5% of the squares. During the second generation 62, 76, 84, and 95% of the squares were damaged by these same populations. Total yields from plots with 0, 14, 25, 50, and 100 overwintered weevils per acre, were 3,454, 2,033, 2,023, 1,365 and 603 pounds of seed cotton per acre, respectively. A slight loss in quality of the lint was observed between the 100 overwintered weevil population and each of the lower populations.

A method was developed at Florence, S. C., for marking and recovering boll weevils for use in movement studies. The weevils were coated with a fluorescent powder which exerted no apparent toxic effect. They were released in cotton, and their movement traced at night by use of a portable black light. In moving about over the plants some of the powder was often brushed off onto the foliage. Thus weevil movement could be detected even after the weevil had moved to other plants. In addition to usefulness in movement studies, this feature of the powder should have many uses in feeding, mating, egg laying, and other biological studies.

Boll weevils survived the winter in cotton bolls installed on the soil surface in the fall of 1961 at Waco, Texas. Several boll weevils emerged in the spring and early summer of 1962 in pink bollworm hibernation experiments from treatments in which bolls were left on the soil surface throughout the winter and from those installed $\frac{1}{2}$ inch

above the soil surface. Very few emerged from bolls buried to a depth of 2 inches in the fall or from those installed 15 inches above ground. No weevils emerged from 100 pounds of bolls which were collected from standing stalks and were installed on the soil surface in hibernation cages in February 1962.

Two hundred Thurberia weevils removed from Thurberia seed pods collected in the Catalina mountains in Arizona in December, 1961, were installed with the debris in 1-foot square screen cages. None of them survived the winter.

Studies were made in Texas and Mississippi to determine whether overwintered boll weevils could locate groups of fruiting plants more easily than single plants. In Central Texas greenhouse grown fruiting cotton plants in groups of 1, 5 and 20 were placed near hibernation sites in 3 cotton fields and in 3 other crop locations in 1960, 1961 and 1962. Each year the most weevils were collected in the largest plant group and the fewest on the single plant. At Stoneville, Miss., where groups of 1, 4, 7, and 16 plants were utilized in 1961, more weevils were collected from the 16-plant group than from the other groups, with the fewest number being collected from the single plant. However, in 1962 no weevils were collected on any of the plant groups at this location.

Studies at Florence, S. C., and College Station, Tex., showed that overwintered female weevils do not have to mate in the spring to produce viable eggs.

Studies at College Station, Tex., showed that male boll weevils 1 to 7 days old or more than 30 days old caused a reduction in the egg production of females with which they mated. The highest production during a 30-day test period was obtained with newly emerged females and 10-day old males.

In field experiments at Florence, S. C., designed to determine how boll weevils are attracted to cotton, the attractant forces of odor, light and electrical energy were studied. It appeared that reflected light is the most important force. Appreciable numbers of weevils were attracted only when the plants or objects of similar color could be seen by the weevils.

Research at Stoneville, Miss., indicated that the reproductive system of the overwintered male boll weevil appears to become functional before that of female. Spermatogenesis in its early stages was observed in 33% of the males obtained from ground trash in early March. No evidence of oogenesis was observed in females collected at the same time.

In studies at Baton Rouge, La., it appeared that diapause induction in the boll weevil was possibly related to the physiology of the cotton plant. A 3-day starvation period immediately after the adults emerged had no effect on the numbers that entered diapause. No significant differences were noted between groups of adults held at different relative humidities or between groups fed with squares from different varieties of cotton. The greatest differences in percentage of diapause occurred among groups of weevils reared at different times of the year which suggests an association with changes in the cotton square brought about by physiological changes in the plant.

An improved mechanical process for the removal of boll weevil eggs from cotton squares has been devised. Certain modifications of those described in published procedures have permitted high egg recoveries with a minimum amount of injury to the embryos. A slow speed blender with rubber-covered blades was used to separate the eggs from squares which had been sliced in half.

The development of 10 external morphological characters of a boll weevil strain was studied at Baton Rouge. The time necessary for development of each of these characters was established. Character changes were in pigmentation and sclerotization. These changes will help to establish the age of the pupae in the study of reproductive development. Mobile sperm were observed in the later stages of pupal development.

Studies on boll weevil rearing at College Station, Tex., showed that disposable petri dishes were satisfactory for rearing weevils. Sterile, disposable, clear polystyrene Petri dishes proved to be more economical than glass dishes. Furthermore, the use of plastic dishes resulted in a better yield of weevils than the glass dishes.

Seven B-vitamins were indispensable for boll weevil larval development in nutrition studies at College Station. These were pantothenic acid, niacin, thiamine, riboflavin, pyridoxine, folic acid, and biotin. Analyses of ascorbic acid in boll weevils maintained on various diets have shown that there is apparently no synthesis of ascorbic acid by the boll weevil. Eggs contain the highest concentration of ascorbic acid of any weevil stage assayed.

Research at Baton Rouge, La., showed that survival of artificial diet-reared adult boll weevils in the laboratory depended on several factors. Survival data plotted for three cultures (F_1 and F_{15} Louisiana; F_9 Mexico) approached the typical sigmoid or semirectangular curve characteristic of an animal population having a senescence. Longevity was variable, and depended upon sex, culture, and holding conditions. Greatest longevity was demonstrated by male weevils from Mexico with a mean of 121.5 days and a maximum of 199 days.

Of 11 known enzyme inhibitors tested at Baton Rouge, sodium ozide gave a 100% kill of boll weevil adults within 24 hours when fed in a diet at a concentration of 0.01%. Several other enzyme inhibitors were also effective in preliminary tests.

In laboratory studies at State College, Miss., boll weevil adults showed significant differences in preference response to plants grown under different light qualities. Weevils preferred dark-grown plants to plants grown in blue or green light. Plants grown under cellophane filters which transmit red, far red and blue were preferred over plants grown in far red, green, and red light, respectively. Cotton plants given ultra-violet irradiation were preferred by boll weevils over untreated plants.

Research on the absorption and translocation of systemic insecticides in the cotton plant at College Station, Tex., showed that phosphamidon, DDT, and methyl parathion were absorbed and translocated upward and downward. Phosphamidon was readily translocated; methyl parathion was translocated much less than phosphamidon; DDT was translocated to a limited extent.

Partial chromatographic separation of the components of Strobane was effected at Baton Rouge, La. Resolution of the components was facilitated by recording their ultraviolet absorption as they appeared in the eluate. With the closely related insecticide, toxaphene, this method of detection will not be as useful because of the compound's weak absorption in the ultraviolet range. Three of the components of Strobane are toxic to susceptible boll weevils. These fractions will also be evaluated as DDT synergists against resistant weevils.

A study of the effect of certain insecticides on ATPase and succinic dehydrogenase activity in the boll weevil was initiated at Florence, S. C. Although sufficient data have not been accumulated to reach final conclusions, it appeared that methyl parathion, dieldrin, and DDT, when added to boll weevil homogenates, do not materially affect succinic dehydrogenase activity. When these insecticides and also endrin were added to homogenates, the levels of activity of ATPase in the treated and control homogenates were not significantly different. Sevin, Strobane, chlordane and heptachlor did not affect activity of ATPase. Dinitro-o-cresol at 10^{6}-M reduced its activity. These results are in contrast to the increased activity reported in the literature for other insects for this enzyme.

In studies on the effect of magnesium on ATPase activity in boll weevil homogenates, there was no variation due to magnesium in the homogenate or supernatant. However, mitochondria require added magnesium for activity.

In physiological studies on the boll weevil at State College, Miss., four typical bases in RNA, and 2 acid soluble compounds and 13 amino acids in the feces were identified. Gonads of reproducing weevils were used in extracting and identifying the RNA bases, guanine, adenine, cytosine and uracil. Uric acid and guanine were tentatively identified in the feces. Eleven amino acids positively identified in the feces were isoleucine, valine, praline, phenylalanine, arginine, threonine, alanine, glycine, glutamic acid, serine, and aspartic acid. Tentatively identified were tyrasine and methionine.

Paper electrophoresis of the cytoplasmic fractions of adult boll weevils at Baton Rouge, La., revealed an isodynamic mixture of 4 enzymes capable of hydrolyzing the pyrophosphate bond. A major portion of the enzyme activity (85.2%)occurs as a weak anionic protein but there are three other enzymes also capable of cleaving the substrate which account for 2.5, 7.6 and 3.1% of the total activity. The first of these proteins is anionic, and the latter two are strongly cationic.

Also at Baton Rouge gas chromatography of the lipids found in artificial larval boll weevil diet and immatures and adults reared on the diet indicate that the weevil is capable of modifying the incoming diet to deposit fatty acids more characteristic of the species than of the food, although the fatty acid makeup of the larval diet was atypical. When compared with squares, the weevils developing on the diet had fatty acids similar to those in the square with respect to carbon chain length and degree of unsaturation. The data also suggest that stored fat is utilized as a source of energy during metamorphosis since a 50% decrease in total lipids was measured during the transition from pupa to adult.

Juvenilization, or the appearance of true juvenile characteristics in an adult insect due to treatment with hormone extracts, has been obtained at Baton Rouge by treating honey bee pupae and silkworm pupae, but not with boll weevil pupae. Queen bees emerging from topically-treated pupae had patches of thin, white cuticle at the treatment site. Diapausing silkworm pupae (Promethea) were injected with a hormone extract, and all produced positive signs of juvenilization. Two of the treated silkworm pupae moulted into nearly perfect second pupae, with only the wings showing adult characteristics. Positive results of a rather sporadic nature have also been obtained by treating Tenebrio molitor pupae.

The major fatty acid components of adult boll weevils were identified by gas-liquid chromatography at Baton Rouge, La. Approximately 100 separate analyses of both reagent-grade fatty acids and those extracted from adult weevils have been made. The major effort of the work thus far has been in selecting standard conditions for future assays. The fatty acids are typical of those encountered in other animals fats,

and no unique ones were detected. The percent composition of the fatty acid fraction of the adult boll weevil showed no significant changes of any particular chain length or degree of saturation during the transition into diapause in the laboratory. Although there were some variations between samples, the fatty acid complex was much the same in nondiapausing and laboratory-induced diapausing weevils. This is interpreted to mean that during the accumulation of fat all the fatty acids are increased with no one type or carbon chain length being selectively synthesized. It is not known if this will also hold true for diapause induced under field conditions. The fatty acid fraction is a complex mixture of 23 fatty acids ranging in chain length from 6 to 20 carbon atoms. Of these 23 acids, 8 of them account for 98% with the remaining 15 acids making up 2% of the total fatty acids. The 8 major acids are: myrstic (C_{14}), palmitic (C_{16}), palmitoleic ($C_{16:1}$), heptadecanoic (C_{17}), stearic (C_{18}), Oleic ($C_{18:1}$), linoleic ($C_{18:2}$) and linolenic ($C_{18:3}$). It is believed that a study of these 8 major acids should provide a clear and concise idea of fatty acid metabolism in this species with regard to lipid buildup during diapause. Approximately 60% of the fatty acids contain at least one double bond. These unsaturated acids occur mainly in the C_{18} series. The remaining 40% of the fatty acids are saturated, of which palmitic (C_{16}) is the main one, accounting for 30% in itself.

Preliminary identification of neurosecretory centers of boll weevil has been obtained at Baton Rouge. Histological tests with special neurosecretory stains revealed large dark-staining cells in the brain and some very conspicuous ones in the suboesophageal ganglion. Although evidence is fragmentary and more slides are being prepared, it appears that some of the largest (and presumably most active) cells are found in reproducing females.

Gas chromatography of the fatty acids contained in the triglyceride fraction of the total body fat of the boll weevil revealed the presence of myristic, palmitic, palmitaleic, heptadecanoic, stearic, aleic, linoleic, and linolenic acids. These are the same major components reported previously for unfractionated body fat, and the proportions are of the same order of magnitude. Most of the minor acids originally found in the total lipid extract were not detected.

The relative amounts of the major fatty acids in the phospholipids of the boll weevil were found to differ from those in the triglycerides. Linoleic and linolenic acid are more abundant in the phospholipids. Palmitic acid, a major triglyceride component appears to be a secondary constituent in phospholipids.

2. Pink Bollworm. Fecundity and longevity data have been obtained at Brownsville, Tex., for populations of laboratory-reared pink bollworms at 70°, 80°, 90°, 100°, and 105° F., with a relative humidity of 75% to 100%. Data were obtained on individual pairs with sugar solution available for food and young, pubescent cotton leaves for oviposition. The leaves were placed on wet paper toweling at the two highest temperatures to prevent rapid desiccation. A test to determine the influence of wet toweling was made at 90°. The LT-50's of the female populations were pivotal ages of 31.5, 22.5, 13.5, and 9.5 days at 70°, 80°, 90°, and 100°, respectively. The LT-50's for the males were 32.5, 23.5, 16.5, and 9.5 days for the respective temperatures. The mean total fecundities were 220.8, 157.4, 130.4, and less than 1 egg per female for the respective temperatures. Frequency distributions of fecundity indicated an increase in the proportion of females with very low fecundity with increases in temperature. The fecundity and longevity at 105° were quite similar to those at 100°. Comparisons with wet toweling at 90° showed an increased fecundity (151.8 vs. 130.4 eggs per female) and decreased longevity (LT-50 10.5 vs 13.5 days) with the toweling. The proportion failing to reproduce was decreased by use of the moist toweling.

Studies involving 50 individual virgin pink bollworm females showed that 76% of them deposited infertile eggs. The average number of eggs per ovipositing female was 53 with a range of 1 to 177. The maximum number of eggs produced (234) by the groups occurred when the moths were 20 days old. The age of moths at the last day of oviposition ranged from 14 to 39 days with the mode of 20 days. The average moth longevity was 26.5 days (temperature 85° ± 5° F.).

Matings of 94 individual pairs of pink bollworm moths under continuous light (12 foot-candles), observed continuously for 21 days, showed that 74.5% of the pairs mated. Of 100 matings observed, 71% were single matings, 20% double matings, and 7.1% triple matings. One pair mated seven times, but indications are that some of these were not true matings. The duration of mating ranged from 3 minutes to 26 hours and 50 minutes. The mode was between 1 and 2 hours. The daily maximum number of matings for the group occurred when the moths were 6 days old. Mating occurred initially among 4-day-old moths and continued through the 17th day. In studies of multiple pairs caged together, mating occurred initially among $2\frac{1}{2}$-day-old moths while the mode for the duration of matings was similar to that in the individual pair studies.

The use of barriers between first-instar pink bollworm larvae improved the rearing technique for the insect. Rearing of pink bollworms on synthetic media in the past has been confined largely to the use of vials containing the media with one larva per vial to avoid mortality

from crowding which resulted when several were placed in a container. It was found that good numbers may be reared by using 3/4 inch cubes of medium spread in layers interspersed between cotton barriers in a glass jar or other container. Groups of newly hatched larvae are introduced on the cubes in successive placements of medium- and barrier-layers.

Excluding the genus Gossypium, the preferred host of the pink bollworm, 46 plant species have been recorded as secondary-food plants of this insect in the United States and Mexico.

Population increases of the pink bollworm on caged cotton were studied in 1960 at Brownsville and Waco, Tex., and Stillwater, Okla. Planting dates were March 11, March 29, and May 10 at the respective locations. Squaring began May 1, and just prior to May 31 and June 26 at the respective locations. Fifteen pairs of pink bollworm moths from laboratory cultures were introduced into each of two cages at each location when the first firm, green bolls were found (June 20 at Brownsville, July 5 at Waco, and August 9 at Stillwater). The fruiting pattern was similar at the three locations with the peak number of bolls found 30 to 40 days after infestation. The plants at Waco developed a high incidence of Texas root rot which confounded the study there. The number of bolls produced at Brownsville was higher than at Stillwater. The peak number of larvae of the first generation occurred about 20 days after infestation at each location. This generation was apparently greater at Stillwater than at Brownsville. Three generations were produced at Brownsville, but only two at Stillwater, and two and a half at Waco. The cotton at Brownsville ceased fruiting September 1, while that at Stillwater continued until frost (October 20). Overwintering populations were lower at Brownsville than at Stillwater because of a lower proportion of diapause larvae in the open bolls and a very low number of bolls available for reproduction of the last generation at Brownsville. The first diapause was found at Brownsville during mid- and late-August, while it was first noted on October 5 at Stillwater. Based on overwintering populations, the population increase averaged 1.5-fold per generation at Brownsville and 8.9-fold per generation at Stillwater. Analysis of data of a similar study in 1961 is incomplete.

Increased diapause of pink bollworm larvae reared in bolls, resulting from exposure to a temperature regime with a mean of 70° F. (vs. mean of 84°), took place when the exposure occurred during the first and/or second instars, but not when the exposures occurred during the later instars. Sixty percent of the larvae exposed to this temperature in the first instar and 40% of those exposed in the second instar entered diapause when developing in a constant 14-hour photoperiod. The mean 70° F., compared with a higher temperature, reduced the effect of a photoperiod favorable for the formation of a high proportion of non-

diapause larvae. The percentage entering diapause during increasing and decreasing photoperiods (13 to 16 and 16 to 13 hours) was 58% and 89% respectively, compared to 8% and 71% at a mean of 84°. Statistical analysis showed no significant difference in the proportion that entered diapause between larvae reared in bolls 1 to 10 and 11 to 20 days old in the photoperiodic studies. However, the proportion in diapause in 21- to 30-day-old bolls was significantly higher than in any of the other age groups.

Pink bollworm moth emergence records indicated that photoperiod influences the termination of diapause. When open bolls infested with diapause larvae were soaked in water and lots held at similar temperature under six photoperiods, significantly greater numbers of moths emerged from the lots held under photoperiods of 13, 14, and 15 hours than lots held under photoperiods of 10, 12, or 16 hours. Since the former photoperiods are those that result in production of the greatest number of nondiapause larvae, it appears that the induction and termination of diapause may be under similar photoperiodic control.

In cold tolerance tests, the metabolic rates of diapausing pink bollworm larvae, conditioned at 55° to 60° F., measured at 60° and 86° were greater than that of larvae conditioned at 80° and 85° for conditioning periods of 7, 17, and 21 days. The larvae conditioned at the lower temperature also exhibited higher survival from a 1-hour exposure to 10° C.

DDT resistance of pink bollworms in Mexico has become more obvious. Moths emerged from cotton harvested near Torreon, Coah., Mexico, were about 13 times more resistant to DDT than were moths from El Paso. No evidence of cross-resistance to Guthion or Sevin was observed in laboratory tests. Selection of a laboratory culture of pink bollworms with a dose of DDT that killed approximately 33% of the moths has resulted in a 5-fold increase in the LD-50 to DDT in 10 generations. The WARF anti-resistant compound did not potentiate the toxicity of DDT to the resistant pink bollworm moths.

3. Other Cotton Insects. Data from feeding tests at Brownsville, Tex., did not agree with reports of other investigators that bollworm adults require food before mating. When Heliothis zea and H. virescens adults were given water only, about 30% of each species laid fertile eggs compared to 53% and 77%, respectively, when fed a sugar solution. Feeding on the sugar solution resulted in increased longevity, percentage of moths that oviposited, and total number of eggs laid. These effects were greater for H. virescens than H. zea.

Cabbage loopers were reared successfully on a semi-synthetic diet at Brownsville. The rearing technique was employed for six generations with virus infections limited to less than 5%. Cabbage loopers were

reared in jars coated with the basic pink bollworm diet fortified with ascorbic acid and cotton leaf meal.

Studies revealed that linolinic acid is more active than linoleic acid in bollworm nutrition. When fats were replaced in the basal larval diet with linoleic or linolenic acids, incomplete adult emergence was obtained with linoleic acid. Complete emergence was obtained with linolenic acid and fertile eggs were obtained from the moths.

In studies of the metabolism of dimethoate by the bollworm, it was found the fifth instar bollworm larvae metabolize injected dimethoate very rapidly; large amounts were also excreted. These studies indicated the presence of eleven metabolites, six of which have been tentatively identified.

B. Insecticidal and Cultural Control.

1. Boll Weevil. The Florence, S. C. station conducted a large-scale community early-season boll weevil control experiment at Wallace, S. C., in 1961 which involved 1895 acres of cotton. It was highly successful in holding weevil populations to a low level during the application period and for periods of 4 to 8 weeks after applications were stopped. Applications of Guthion at 0.25 pound per acre or Guthion + DDT at 0.25 + 0.5 pound per acre, were made on a 5-day schedule beginning on June 6 and continuing until the first week in July. Late-season applications were made for the protection of bolls against weevil damage.

Overwintered boll weevil populations were materially reduced in two communities at Tallulah, La., with Guthion spray in 1961. In one community, comprised of cotton fields with 110 acres of uniformly late-planted cotton, four applications of Guthion were made at 5-day intervals from June 28 through July 12. In the majority of these fields, it was not necessary to resume boll weevil control measures for 4 weeks. In the other community, comprised of 15 cotton fields and 140 acres with a difference of over 30 days in the planting dates of some of these fields, four to six applications were made at 7-day intervals from June 8 to July 18. In a few of the early fields, control measures were resumed in a little over two weeks, but in a few late fields, control measures were not necessary for over six weeks.

In small field plot tests at Florence, S. C., sidedressings of Bayer 39007 dust applied at 10 pounds of actual toxicant per acre to cotton plants two weeks after square production began caused significant mortality of adult weevils confined on foliage up to 30 days after treatment.

Preliminary tests at Florence in which cotton squares on field plants were dipped in test treatments, indicated that the addition of various surfactants increased the effectiveness of insecticides against boll weevil larvae in squares. Combinations of phorate or methyl parathion with several surfactants resulted in decreased emergence of adults from squares compared with untreated squares.

In a study to determine the seasonal variation in the susceptibility of the boll weevil to Guthion, topical application tests at Florence indicated that late-season weevils were significantly more difficult to kill than overwintered weevils.

In studies on the effects of insecticides on the cotton plant at Stoneville, Miss., no significant differences were found in total yield of seed cotton between treatments of organophosphorus, chlorinated hydrocarbon, and carbamate insecticides. Treatments which picked less cotton at the first picking (Guthion, methyl parathion, and toxaphene) picked more than the other treatments (endrin and Sevin) at the third picking. Sevin was the only insecticide treatment which had a total yield greater than the untreated check.

In continuing studies on systemic insecticides at College Station, Tex., American Cyanamids 43356 and 43064 were considerably more effective than phorate against the boll weevil in laboratory tests. Used as seed treatments at 1 pound per acre these insecticides gave excellent boll weevil control in the laboratory for 11 to 12 weeks after planting. They were as effective when used as seed treatments as a standard phorate seed treatment against spider mites and the cotton aphid.

In 9 experiments conducted at Waco, Tex., in 1961, the average increase in yield, resulting from cotton insect control, for treated over untreated plots was 1,048 pounds of seed cotton per acre or 426%. This increase compares with an average of 363 pounds or 50% for the 22-year period, 1939-1960, that such records have been made.

In field tests conducted in Mississippi, Texas, and Louisiana, materials that proved effective against adult boll weevils were Bayer compounds 25141, 41831, and 29493, Geigy 30494, Stauffer R-1504, methyl trithion, and Dow's Zectran.

2. Pink Bollworm. In work by the Brownsville, Tex., station field demonstrations showed conclusively that DDT alone is no longer effective against the pink bollworm in the Laguna region of Mexico. Undoubtedly most of the failures reported with insecticides in recent years can be largely attributed to the use of this insecticide. Both Guthion-DDT and Sevin were very effective, and gave excellent control in these demonstrations. Although BHC-DDT dust mixture did not give as good a reduction in the infestation as Sevin or Guthion-DDT, this

insecticide mixture, in most instances, held the pink bollworm population below the damaging level.

Laboratory studies of the joint action of some commonly used insecticide mixtures containing DDT against DDT-resistant pink bollworm moths indicate that toxaphene does not act as a synergist for DDT. Good evidence of synergism with BHC-DDT mixtures was obtained. Candidate insecticides showing promise in laboratory tests against the pink bollworm were Bayer 32651, 37344, 38156, 39193, 43356, 46676 and 47940; Stauffer R-1504 and N-2404; Monsanto CP-40273; and Upjohn TCU-12927.

Past studies at Brownsville indicated increased winter mortality of pink bollworm larvae in bolls buried in sandy soil as compared with those in heavier types. A 3-year study has been completed to attempt to determine whether this increased mortality occurs in the winter or in the spring just prior to emergence. The study was made under field-cage conditions. The data showed no significant differences in mortality due to soil type regardless of time of exposure in two of the three years. One year showed significantly higher survival in silty clay loam than in river sand for larvae first exposed in the fall or just prior to spring emergence.

Winter survival of larvae in burried bolls at Heavener and Chickasha, Okla., was less than 1% in 1961. At Las Cruces, N. Mex., survival was lower in bolls buried in December than in those buried in March, but no differences were produced by winter irrigation.

Hibernation studies of the pink bollworm indicate that the time between plow up and planting of the cotton crop in Arizona is not sufficient to destroy the pink bollworm. Bolls buried on November 16, 1961 at 2-, 4- and 6-inch depths were only partially decayed and seeds were sound when examined 3 months later despite heavy rainfall during December. Under such conditions diapausing pink bollworm larvae in the seeds would have survived.

3. Other Cotton Insects. In field tests at Waco, Tex., there was no significant difference in thrips control obtained with American cyanamid 43064 as a seed treatment at 1 pound or as an in-furrow granule application at 2.4 pound at planting and phorate as a seed treatment at 1 pound per acre. Three and 4 weeks after planting, kill of weevils caged on plants in the AC-43064 seed treatment was 74 and 20%, 87 and 59% and the AC-43064 in-furrow granule treatment, and 80 and 19% in the phorate seed treatment. Kill in all treatments was very low after 5 weeks. At Stoneville, Miss., the thrips infestation was too low to evaluate control with 2 pounds of AC-43064 per acre applied as granules in the furrow at planting time. Kill of weevils caged on the plants in the treatment 2, 3, 4, 5, and 6 weeks after planting was 92.5, 53, 9, 8 and 0%, respectively.

Several candidate insecticides were tested in the field. Those effective against thrips were Bayer 29493, 37344, and 25141, Shell 4402 and 3562, Geigy 30494, and Stauffer R-1504. Insecticides applied in pre-merge herbicide treatments failed to control thrips after the cotton came up. Shell SD-4402, Bayer 41831, and Strobane or toxaphene plus DDT gave excellent control of bollworms. Bayer compounds 25141 and 29493, Dibrom, Shell SD-3562, Geigy 30494, Stauffer R-1504 and Zectran were as effective as a toxaphene plus DDT standard against the tarnished plant bug. Dibrom and Shell SD-3562 gave good control of the cotton aphid. Bayer compounds 25141 and 29493, Shell compounds SD-3562 and SD-7438, American cyanamid 43073 and methyl-ethyl Guthion gave spider mite control equal to standard materials. Zectran, Trithion and Stauffer R-1504 were effective against the cotton leafworm.

Laboratory tests were, also, conducted with candidate insecticides. American Cyanamid 38023 and Bayer compounds 39007, 45556, 47185, 25141, 47043, 47940, 47416, 47043, and 44646 all showed promise against adult lygus bugs. Bayer compounds 32651, 37289, 38156, 37344, 44646, 36743 and 38920; Zectran; Monsanto compounds CP 40273, CP 40272 and CP 40294; Stauffer N-2404; General Chemical CP-1283, Hercules 9699, Shell SD-7438 and Upjohn TCU 12927 were effective against bollworms. Although Guthion did not show high toxicity to bollworm larvae when applied alone, combinations of it with methyl Guthion were about as effective as methyl Guthion alone. Bayer 44646 was effective against the beet armyworm and cotton leaf perforator. Bayer 47940, Hercules 7522 and American Cyanamid 47031 were as effective against boll weevils as Guthion. Others showing promise against this pest were Bayer 45556, American Cyanamid 47071, Stauffer 2790, Hercules 8717 and 9699, and Union Carbide 8305. Materials effective against the salt-marsh caterpillar were Bayer 36743, Hercules 5727, and Stauffer compounds N-2230, N-2404, and R-1504. Those that gave good kills of cabbage looper larvae were Bayer compounds 36743 and 44646, Monsanto compounds CP-40273 and CP-40294, Stauffer N-2404 and Zectran. Bayer compounds 32651, 37344 and 44646; Stauffer compounds N-2790, N-3054 and N-3055; Upjohn TCU-12927 and Zectran were effective against the cotton leafworm.

C. Insecticide Residue Determinations.

1. Residues on Cottonseed. An experiment was conducted in 1961 at Brownsville, Tex., to determine the magnitude of residues of BHC and DDT resulting from applications of these insecticides to cotton after bolls begin to open. Seed cotton was harvested from the various treated plots, ginned and the cottonseed was analyzed for residues by the Division's Pesticide Chemicals Research Branch. No detectable BHC residues were found when whole cottonseed was analyzed from plots treated 1, 3, 4 or 5 times at an approximate rate of 0.5 pound of gamma BHC per acre between June 16 and July 6. DDT residues ranging from 2 to 4 parts per million were found on whole cottonseed

with the above treatment schedules of DDT at 3.3 pound per acre.

D. Biological Control.

1. Boll Weevil. In tests at Florence, S. C., to evaluate the effectiveness of Nematode DD-136 as a boll weevil biological control agent, nematodes were applied at rates of 10,000, 50,000, and 100,000 per row foot and combined at the 50,000 per row foot rate with methyl parathion at 0.125 pound per acre. Nematode recovery was made from squares, boll weevil larvae and adults; however, the maximum weevil mortality was only 30%. Under the conditions of this test the use of the nematode as a control agent did not appear promising.

Encysted amoebae were found for the first time in boll weevils obtained from hibernation sites near Tallulah, La. It is not known whether the amoebae are pathogenic or saprophytic. In addition, nematodes were found for the second year in weevils taken from ground trash. Each infected weevil yielded from 1 to 6 large nematodes.

Beauveria bassiana was capable of infecting overwintering boll weevils when it was applied to a hibernation site. Fifty percent of the live weevils collected from the ground trash in the favorable overwintering, treated site died of the fungus after being brought into the laboratory. This indicates that the weevils were infected in the field or that spores were on the integument and still capable of infection causing death when conditions became favorable for fungus growth. Further tests are in progress to determine usefulness of B. bassiana as a control measure against overwintering boll weevils.

Two spore diseases, one of which has been tentatively identified as Triboliocystis garnahani, have been common in various laboratory boll weevil cultures. Dead adults from Presidio and College Station, Tex., and State College, Miss., cultures all contained spores in large quantities. Thurberia weevils and boll weevils from Caborca, Mexico, cultures were not infested. Weevils from a College Station culture also contained a spore of a different type. Biopsy of one of the males showed the testes to be packed with the spores.

2. Pink Bollworm. The temperature spectrum of Bacillus thuringiensis and pink bollworm larvae are apparently coincident and, therefore, ideal for control once the larvae pick up a lethal dose as determined from experiments conducted at Brownsville, Tex. The optimum temperature (based on LT-50 hours) for progression of mortality in long-cycle pink bollworm larvae was 40.1° C. No septicemia was detected at 51.2° and 8.6°, but was observed for eight temperature levels between these two extremes. Larvae exposed to 8.6° and then transferred to an optimum temperature reflected a mortality pattern similar to the optimum temperature.

Relative humidity is not a factor in the progression of mortality in long-cycle pink bollworm larvae injected with a lethal spore dose of B. thuringiensis. Larvae exposed at 100%, 69%, 24% and 0% relative humidity had LT-50 values of 10.0, 10.1, 9.9, and 10.0 hours, respectively.

Studies conducted at Brownsville of the effects of temperature on growth, spore-germination, and generation-time for B. thuringiensis showed that no visible growth occurred on either solid-media slants or slides held continuously at 51.2° or at 8.6° C. However, when slides or slants were exposed at 51.2° for 2-4 hours or at 8.6° for 60-240 hours and then transferred to an optimum temperature, a growth did develop. These data corroborate the data obtained from studies dealing with the insect host. Bacterial growth in the 51.2° transfers was probably due to additional spore-germination and not to cell development from previously germinated spores. The time required for spore-germination and generation-time showed an inverse relationship to the temperature level at which spores were incubated. No germination was observed at 8.6° after 300 hours' exposure although spores exposed to eight temperature levels between 51.2° and 8.6° all showed a measurable increase in size. The shortest germination-time was recorded at 51.2°; however, microscopic observations showed that vegetive cells at this high temperature develop abnormally and rarely divide beyond the 2-cell stage.

Approximately 95% mortality was recorded when long-cycle pink bollworm larvae were exposed in petri dishes to 7×10^9 B. thuringiensis spores/gram of soil. The percent mortality for decimal dilutions of 7×10^9 spores/gram were: 68.7, 41.0 4.5, 2.5, and 0.0, respectively. When short-cycle pink bollworm larvae were exposed to spores sprinkled over the soil surface and spores mixed with topsoil in laboratory cages, the topsoil treatments gave a reduction of 69.4% and the mixed soil treatment 64.5% compared with the check. It is believed that spore pickup was via the cuticle.

In field-cage tests, B. thuringiensis dusts applied to the top 2 inches of soil and to seed cotton reduced the number of emerging pink bollworm adults by approximately 45% over that of the check. Viable spore counts made on treated soil after 7.28 inches of rain and approximately 4 months' exposure showed a reduction from 11.7×10^7 spores/gram of soil to 1.1×10^7 spores/gram.

3. Other Cotton Insects. The pathogen, Bacillus thuringiensis failed to give bollworm control in field tests in Arizona. In laboratory and field tests, it was effective in controlling the cotton leafworm. Larval feeding was inhibited almost immediately by the disease and did not continue unless the larvae were placed on untreated leaves.

In insect pathogen studies at Brownsville, Tex., a cage test to test the effects of a polyhedral virus suspension against cabbage loopers on cotton showed outstanding control of this insect by the virus. Initial trials to rear cabbage loopers on a synthetic diet and to infect the larvae with polyhedrosis to serve as a source of supply for experimental use show promise. Further information is being obtained to improve techniques as well as to obtain data on cost and yield. Preliminary information indicates that the technique may be readily adapted to commercial production of the virus. Chelonus blackburni appeared unpromising as a pink bollworm parasite. A low parasitism occurred on caged cotton, even when adults were released in numbers equaling 20-80 times the number of host adults. The female parasite actively searched for hosts, but this search was primarily confined to the top foot of the plant.

Adults of the parasite, Pristomerus hawaiiensis, received from Hawaii, showed no interest in the potato tuber moth as a laboratory host. Several adults were obtained from the first generation developing in pink bollworms infesting caged cotton.

In Arizona natural enemies and insecticides affect the seasonal abundance of cotton insects. In Pima County where little insecticide was used to control cotton insects, the bollworm, cotton leaf perforator and cabbage looper, did not reach peak populations in 1961 until mid-August or later. Natural enemies of these insects are not adversely affected by early applications of insecticides. In fields where no early insecticides were applied, beet armyworm populations reached their peak in May and quickly disappeared in June. In Maricopa County where insecticides were used throughout the season, cotton was damaged by the armyworm from the seedling stage until the plants were mature.

E. Insect Sterility, Attractants and Other New Approaches to Control.

1. Boll Weevil. Late-season applications of methyl parathion in 1961 in the Upper Big Bend Region of Mexico-Texas reduced the population of boll weevils capable of surviving the winter by approximately 88%. Four applications were made to approximately 2800 acres of cotton in which this reduction was indicated. Infestations were found about 30 miles farther upriver than in 1960. However, in these areas, newly infested by late-season migration, the adults did not diapause but remained reproductive until frost. Results of this post-season method of boll weevil control cannot be fully evaluated until late in the 1962 cotton growing season.

In a late-season boll weevil control experiment at Stoneville, Miss., 1961 spring populations of overwintered weevils were estimated at 3.9 per acre in a field which had been treated with methyl parathion during the fall of 1960. A total of 19 overwintered weevils were

recovered June 28-July 26 in a trap planting of cotton, 1/30 acre in size, at the site where a five-acre planting had received seven applications of methyl parathion at weekly intervals from September 14 to October 26, 1960. Overwintered weevils in a comparable untreated field emerged on seedling cotton at the rate of 292 per acre. Boll weevil populations entering hibernation quarters were greatly reduced by fall applications of methyl parathion spray in a diapause control study conducted in DeSoto County, Miss., on a rather isolated cotton planting of 270 acres. Five applications of methyl parathion and a desiccant, which was used to terminate plant growth, were applied in the test. Some of the weevils in the field population attained firm diapause in October. However, at a given location in the test area, a ground trash sample taken in the fall of 1961 yielded 1/7 or 14% the number of weevils found at the same location in the fall of 1960. On June 27, 1962, the percentage of punctured squares ranged from 0.4 to 1.4 in fields in the fall treated area. The average in untreated fields was 3 to 12%.

Boll weevil populations were very low in cotton fields receiving post-season control applications in the fall of 1960 and in adjacent woods trash at Tallulah, La. During May and June of 1961 field populations of overwintered weevils averaged 35 per acre in three areas receiving post-season applications of insecticides in the fall compared with 75 in four comparable check areas which received no post-season treatments. The average number of weevils found per acre during March-April of 1961 in woods trash adjacent to fields receiving post-season treatments in the fall was 83 compared with 914 in three comparable check areas where post-season treatments were not made. In similar treated areas in the fall of 1961, the average overwintered boll weevil population in early summer of 1962 was 30 per acre and compared with 80 in untreated fields.

Several dozen candidate chemosterilants were screened against the boll weevil at College Station, Tex. These tests showed that apholate, although quite toxic to the boll weevil, will sterilize it. A field cage test in which this chemosterilant was evaluated for its effectiveness in sterilizing males and reducing population increase, indicated that the sterile-male technique of insect control is promising against the boll weevil. A 20:1 ratio of sterile males to normal males reduced the population increase about 75%. Laboratory tests conducted with various ratios of apholate-treated to untreated male boll weevils caged with females showed that treated males are not as competitive as untreated males.

A powerful boll weevil arrestant and/or feeding stimulant has been extracted from cotton. This material does not attract weevils from a distance but causes them to stop when they come in contact with it and it apparently stimulates feeding. The arrestant is extracted from cotton plants with water. The boll weevil will feed on bean pods,

bean seedlings, cork, filter paper and other generally ignored substrates when the substrate is sprayed with the extracted arrestant. Removal of the water-soluble arrestant from squares causes the weevil to ignore them. However, when solvents other than water are used, the weevils will feed on the extracted squares. The potential use of the arrestant in weevil control and its chemical structure now are being investigated. A sensitive, fairly accurate and relatively simple biological assay for determining arrestant concentration in plant parts has been developed. The method utilizes an inert substrate of agar plugs impregnated with the arrestant solution and scores arrestant concentrations as a function of numbers of feeding punctures. When square components were assayed, the concentration gradient of the arrestant was highest from the outside (calyx) of the square to lowest on the inside (ovary). Genetically different lines and species of cotton showed marked differences in arrestant concentrations when assayed biologically. The laboratory findings are in agreement with what is known of the boll weevil's preference for these lines and species when grown under field conditions. The same preference difference, apparently due to arrestant concentration, existed between seedlings of the genetically different lines as between the squares of the lines. Thus it appears possible to use seedlings in a host-plant-resistant screening program, thereby saving time and space requirements.

In research at College Station investigating the attraction of the cotton plant to the boll weevil, laboratory tests were designed to determine if the weevil could "smell" a cotton square or boll. Techniques were used that ruled out other means such as shape, color, size and taste. Results indicated that weevils were attracted to squares and bolls by an odor.

Several hundred fermentation liquors and plant extracts were screened against the boll weevil to evaluate possible toxicity to larvae in squares, effects on fecundity, attractancy, and repellency. This research is being conducted at Florence, S. C., in an attempt to induce immunity in the cotton plant to this pest. Results to date have been negative.

Several hundred materials were screened for attractancy or repellency to the boll weevil at Brownsville, Tex. None were found to be highly attractive or repellent.

2. Pink Bollworm. In radiation studies, pink bollworm adults from irradiated pupae oviposited eggs when the dose was greater than 10 kr, the previously reported dose at which no oviposition occurred. Pupal susceptibility was dependent on age at the time of treatment, i.e., sensitivity to radiation decreased with increased age of the pupae. This inverse trend was most striking in the total eggs produced and

percent that hatched. Females from 5-day-old pupae irradiated with 10 kr were more susceptible than males, as indicated in fecundity tests. Tests to determine the margin of safety between a sterilizing dose and the dose at which abnormal moths resulted showed that there was overlapping of these dosages for 1-day-old pupae and also 3-day-old pupae. For example, 43% of the adults from 1-day-old pupae treated at 5 kr were abnormal, but still 1% of the eggs hatched. There was a wide range in the safe sterilizing dosage for 7-day-old treated pupae; no abnormal adults occurred at 40 kr treatment and 30 kr was sufficient to prevent any egg hatch.

In pink bollworm chemosterilant studies, aphoxide appeared promising in feeding tests although high mortality was encountered. The effects of pupal submersion and topical application on adults have been variable, probably due to polymerization of apholate and aphoxide.

The empirical screening of chemical compounds for attractancy to pink bollworm moths was continued. To date no highly attractive substance has been observed. Present knowledge indicates that substituted 6-membered ring compounds, either aromatic or saturated, in combination with secondary or tertiary ethers, esters, or amides are most attractive.

In laboratory tests, an extract from mating pink bollworm moths was highly attractive to the males. This extract was competitive with the lure of females in mixed populations. It remained attractive after exposure for a minimum of 19 days. The lure has been highly promising in field tests conducted in Mexico in 1962. Good catches of male pink bollworm moths from overwintered larvae were obtained in a heavily infested area. "Dixie-Cup"-type traps baited with 100 female equivalents of the lure caught about 15 male moths per trap per night. Traps remained effective 5 to 6 days.

3. Other Cotton Insects. Experimental cotton strains differed in attractiveness to thrips in tests at Stoneville, Miss. Significant differences in the number of thrips per plant occurred on eight experimental strains of cotton. Meyers-8, Smoothleaf SR-2, and Red Plant strains were most susceptible. Yugoslav Early, Coastland R N, and Nectariless strains were intermediate while Asiatic strains A_2-15 and A2-17 had fewer thrips per plant. The most susceptible strains had more than twice as many thrips per plant as the Asiatic strains.

Studies at Tucson, Ariz., showed that an insect-susceptible cotton variety, Glandless 38-6, suffered significant losses in square drop when exposed to high lygus bug populations. Analyses of data from square counts show that the percentage of squares set that made bolls was lower on Glandless 38-6 than on any other variety and significantly less, statistically, than on three-fourths of the other varieties tested. The unusual attractiveness to insects of this variety may be

related to the absence of gossypol.

F. Evaluation of Equipment for Insect Control and Detection.

1. Pink Bollworm. Tests at Mesilla Park, N. Mex., showed that practically all pink bollworm larvae in lint during the ginning operation were killed or removed before the lint reached the lint cleaner. The live larvae remaining in the lint were killed when passing through saw-type lint cleaners. Some survival was found in waste from pneumatic-type lint cleaners. No survival was found in fan-treated lint cleaner waste.

Tests were made to determine larval mortality in gin trash entering a 23-inch trash fan at a 90° angle. The current quarantine regulations for this fan require a maximum $10\frac{1}{2}$- to 11-inch diameter inlet pipe with at least 58 inches of straight pipe between any elbow and the fan housing. The use of a $14\frac{1}{2}$-inch piping inlet with a 90° elbow placed immediately adjacent to the fan housing gave mortality similar to that in previous tests with inlet installations meeting quarantine requirements. However, the mortality was affected by the fan speed. As a result of these studies, the Texas quarantine requirements have been changed to permit more convenient and less expensive installation of inlet piping to trash fans.

An argon glow lamp trap equipped with a fan blowing a stream of air into the funnel at 200 feet per minute showed a 3- to 5-fold increase in the collection of pink bollworm moths over one without a fan. The overall collections of other insects were increased also.

In tests with a portable air suction machine for collecting cotton insects, the machine collected a few more boll weevils from cotton in the early squaring stage than an individual hand picking them during the same time interval. Populations of other cotton insects may be studied quantitatively with this machine

G. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. Experimental cotton strains showed considerable variations in amount of square injury by boll weevils but no difference in weevil mortality in squares in tests at Stoneville, Miss. The average percent squares punctured by the boll weevil ranged from 0 to 66 in 6 experimental cotton strains. When the most susceptible strains had more than 96% of the squares punctured the least susceptible had less than 9%. Asiatic strains had the fewest punctures, red colored plants were intermediate, and a Yugoslav strain had the highest number of punctures. There was no difference in weevil mortality in squares when a Brownsville, Tex., strain of nectariless cotton was compared with several other experimental strains. More

than 60% of all squares punctured produced weevils in all the varieties tested.

2. Other Cotton Insects. In studies at Brownsville, Tex., two experimental nectariless cotton strains failed to exhibit resistance to the bollworm. Field cage studies had indicated that bollworm control might be possible with these cottons as they lacked a source of food (nectar) for the adults. However, when they were tested in field experiments control was not obtained. The insect showed a preference for one of the strains, NR-293, and the infestation on the other strain, SR-1, was about the same as on commercial varieties.

Six varieties of cotton appeared promising in lygus bug resistance tests at Tucson, Ariz. On the basis of percentages of total set fruit maintained on September 13, varieties exhibiting the most promise were AXTE, Inca, 227-12-1, Pima S-1, Stoneville 7 and Tanguis.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Chadbourne, D. S. 1961. Some histological aspects of the boll weevil. Annals of Ent. Soc. of America. 54(2): 313-6.

Clark, E. W., Richmond, C. A. and McGough, J. M. 1961. Artificial media and rearing techniques for the pink bollworm. Jour. Econ. Ent. 54(1): 4-9.

Clark, E. W., and Glick, P. A. 1961. Some predators and scavengers feeding upon pink bollworm moths. Jour. Econ. Ent. 54(40): 815-6.

Clark, E. W., and Richmond, C. A. 1961. The effect of centrifugal force on pink bollworm larvae. Jour. Econ. Ent. 54(6): 1262-3.

Clark, E. W., and Richmond, C. A. 1962. The effect of aqueous submersion on larval and pupal pink bollworm. Jour. Econ. Ent. 55(2): 167-9.

Fife, L. C. 1961. Factors influencing pink bollworm pupation and moth emergence from overwintering larvae in Central Texas. Jour. Econ. Ent. 54(5): 908-13.

Glick, P. A., and Noble, L. W. 1961. Airborne movement of the pink bollworm, and other arthropods. USDA Technical Bulletin No. 1255.

Hacskaylo, Jos., Lindquist, D. A. and Clark, J. C. 1961. Phorate Accumulation by cotton plants and its recovery from the soil. Jour. Econ. Ent. 54(3): 411-3.

Hacskaylo, Jos., Lindquist, D. A., Davich, T. B. and Morton, H. L. 1961. Accumulation of Phorate by cotton plants from solution and sand culture. The Botanical Gazette. 123(1): 46-50.

Hacskaylo, Jos., Lindquist, D. A. and Davich, T. B. 1961. Dimethoate absorption and its translocation and distribution in the cotton plant. Jour. Econ. Ent. 54(6): 1206-9.

Lambremont, E. N., and Earle, N. W. 1961. Longevity of the boll weevil under laboratory conditions. Jour. Econ. Ent. 54(5): 964-6.

Lambremont, E. N. 1961. Homogenate respiration of diapausing and nondiapausing boll weevils. Annals of Ent. Soc. of America. 54(2): 313-6.

Lambremont, E. N. 1962. Enzymes in the boll weevil--I Dehydrogenasis of the brain and related structures. Jour. Insect Physiology. 8: 181-90.

Lindquist, D. A., Brazzel, J. R. and Davich, T. B. 1961. Fate of DDT and toxaphene applied topically to susceptible and resistant boll weevils. Jour. Econ. Ent. 54(2): 299-300.

Lindquist, D. A., Hacskaylo, J. and Davich, T. B. 1961. Laboratory and field investigations with phorate treated cotton seed. Jour. Econ. Ent. 54(2): 379-382.

Lindquist, D. A., Hacskaylo, J., Clark, J. C. and Davich, T. B. 1961 Systemic activity of dimethoate applied to cotton seeds. Jour. Econ. Ent. 54(6): 1132-5.

Lloyd, E. P., McMeans, J. L., and Merkl, M. E. 1961. Preferred feeding and egg laying sites of the boll weevil and the effect of weevil damage on the cotton plant. Jour. Econ. Ent. 54(5): 979-84.

Lloyd, E. P. and Merkl, M. E. 1961. Seasonal occurrence of diapause in boll weevil in Mississippi. Jour. Econ. Ent. 54(6): 1214-6.

Lukefahr, M. J. and Griffin, J. A. 1962. Pink bollworm development in relation to age of squares and bolls with notes on biology. Jour. Econ. Ent. 55(2): 158-9.

Richmond, C. A. and Clark, E. W. 1961. Activity of larvae and pupae of the pink bollworm subjected to burial. Jour. Econ. Ent. 54(4): 789-91.

Shiller, Ivan, Noble, L. W. and Fife, L. C. 1962. Host plants of the pink bollworm. Jour. Econ. Ent. 55(1): 67-70.

Tsao, Ching H. and Clark, Edgar W. 1961. Absorption and translocation of Di-Syston by cotton plants. Jour. Econ. Ent. 54(6): 1228-9.

Vanderzant, E. S. and Davich, T. B. 1961. Artificial diets for the adult boll weevil and techniques for obtaining eggs. Jour. Econ. Ent. 54(5): 923-8.

Walker, J. K., Jr. and Pickens, L. G. 1962. Egg deposition by boll weevils isolated from males during hibernation period and after spring emergence. Jour. Econ. Ent. 55(2): 268-9.

Wene, G. P., Sheets, L. W. and Woodruff, H. E. 1961. Emergence of overwintered pink bollworm in Arizona. Jour. Econ. Ent. 54(1): 192.

Insecticidal and Cultural Control

Bottger, G. T. and Sparks, A. N. 1961. Laboratory tests with toxaphene, DDT and Sevin against lygus hesperus on cotton. Jour. Econ. Ent. 54(6): 1261.

Bottger, G. T. and Sparks, A. N. 1962. Laboratory insecticide tests against the bollworm. Jour. Econ. Ent. 55(1): 143-4.

Chapman, A. J., Robertson, O. T. and Noble, L. W. 1962. Evaluation of stalk shredders and cutters for pink bollworm control. Jour. Econ. Ent. 54(4): 791-2.

Cowan, C. B., Jr., Davis, J. W. and Parencia, C. R., Jr. 1960. Field experiments against several late-season cotton insects in 1959. Jour. Econ. Ent. 53(5): 747-9.

Cowan, C. B., Jr., Parencia, C. R., Jr., and Davis, J. W. 1961. Control of several cotton insects in field experiments in 1960. Jour. Econ. Ent. 54(5): 1011-4.

Davis, J. W., Parencia, C. R., Jr., and Cowan, C. B., Jr. 1961. Field experiments for control of thrips, cotton fleahoppers and overwintered boll weevils, in 1960. Jour. Econ. Ent. 54(5): 966-70.

Fye, R. E., Hopkins, A. R. and Walker, R. L. 1961. Field experiments on control of overwintered boll weevils. Jour. Econ. Ent. 54(4): 622-4.

Fye, R. E., Hopkins, A. R. and DuBose, W. P., Jr. 1962. Cotton yields with recommended and experimental insecticides, 1928-1958. Technical Bulletin No. 1264. ARS, USDA.

Graham, H. M., Robertson, O. T., Adkisson, P. L. and Wilkes, L. H. 1961. Further tests of the effectiveness of cotton stalk shredders for controlling the pink bollworm. Jour. Econ. Ent. 54(5): 1057-8.

Lloyd, E. P., Merkl, M. E. and Crowe, G. B. 1962. The effect of boll weevil infestations on yield and quality of cotton. Jour. Econ. Ent. 55(2): 225-7.

Lowry, Wm. L. and Tsao, Ching H. 1961. Incidence of pink bollworm resistance to DDT. Jour. Econ. Ent. 54(6): 1209-11.

McGarr, R. L., Chapman, A. J. and Lowry, W. L. 1961. Field tests with insecticides for pink bollworm control in 1958. Jour. Econ. Ent. 54(5): 972-4.

Parencia, C. R., Jr., Cowan, C. B., Jr., and Davis, J. W. 1960. Control of several early-season cotton pests with insecticides. Jour. Econ. Ent. 53(6): 1051-4.

Pfrimmer, T. R., Lloyd, E. P., Merkl, M. E. and Furr, R. E. 1960. Field experiments with several insecticidal sprays against the boll weevil and bollworm. Jour. Econ. Ent. 53(5): 711-4.

Pfrimmer, T. R. and Merkl, M. E. 1962. Field insecticide tests against several cotton pests. Jour. Econ. Ent. 55(1): 121-4.

Tuttle, D. M., Wene, G. P. and Sheets, L. W. 1961. The cotton leaf perforator and its control in Arizona. Jour. Econ. Ent. 54(1): 67-70.

Tsao, Ching H. and Lowry, W. L. 1960. Factors affecting the tolerance of boll weevils to calcium arsenate. Jour. Econ. Ent. 53(5): 844-7.

USDA, Entomology Research Division, Agricultural Research Service. 1962. Spider mites on cotton: How to control them. Leaflet No. 502.

USDA, Entomology Research Division, Agricultural Research Service. 1962. Lygus bugs on cotton: How to control them. Leaflet No. 503.

Wene, G. P. and Sheets, L. W. 1961. Control of the beet armyworm on cotton in Arizona. Jour. Econ. Ent. 54(1): 192-3.

Wene, G. P. and Sheets, L. W. 1962. Comparison of aerial spray and dust insecticide applications for the control of cotton insects in Arizona. Jour. Econ. Ent. 55(1): 147-8.

Biological Control

Wene, G. P. and Sheets, L. W. 1962. Relationship of predatory and injurious insects in cotton fields in the salt river valley area of Arizona. Jour. Econ. Ent. 55(2): 395-8.

Insect Sterility, Attractants, and Other New Approaches to Control

Brazzel, J. R., Davich, T. B. and Harris, L. D. 1961. A new approach to boll weevil control. Jour. Econ. Ent. 54(4): 723-30.

Davich, T. B. and Lindquist, D. A. 1962. Exploratory studies on gamma radiation for the sterilization of the boll weevil. Jour. Econ. Ent. 55(2): 164-7.

Ouye, Milton T. and Butt, B. A. 1962. A natural sex lure extracted from female pink bollworms. Jour. Econ. Ent. 55(3): 419-21.

Evaluation of Equipment for Insect Control and Detection

Glick, P. A. and Graham, H. M. 1961. Early-season collections of three cotton insects by argon-glow lamp and black-light traps. Jour. Econ. Ent. 54(6): 1253-4.

Graham, H. M., Glick, P. A. and Hollingsworth, J. P. 1961. Effective range of argon glow lamp survey traps for pink bollworm adults. Jour. Econ. Ent. 54(4): 788-9.

Hollingsworth, J. P., Briggs, C. P. and Scales, A. L. 1961. An electrically heated retaining pen for insect larvae. Jour. Econ. Ent. 54(1): 210-1.

Hollingsworth, J. P., Briggs, C. P., III, Glick, P. A. and Graham, H. M. 1961. Some factors influencing light trap collections. Jour. Econ. Ent. 54(2): 305-8.

AREA 10. TOBACCO INSECTS

Problem. Profitable production of tobacco depends on the control of insects, particularly budworms, hornworms, flea beetles and aphids. Insecticides that have proved effective for the control of these insects have resulted in undesirable residues on cured tobacco. Such residues adhere to the leaf through commercial processing into cigarettes and some have been found in the main-stream of smoke from commercial cigarettes. There is, therefore, need for the development of effective methods of controlling insect pests of tobacco that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. This would include more intensive research on lures, traps, sterilization, and other new approaches to control; better utilization of predators, parasites, and diseases of tobacco insects; evaluation of tobacco varieties which resist insect attack; and continued research for chemicals that leave no residue.

USDA PROGRAM

The Department has a continuing program involving basic and applied research on tobacco insects to develop effective control methods that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. The program is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway, and with the tobacco industry. Studies are conducted at Oxford, N. C.; Florence, S. C.; and Quincy, Fla.

The Federal scientific effort devoted to research in this area totals 4.9 professional man-years. Of this number, 1.1 is devoted to basic biology, physiology and nutrition; 0.6 to insecticidal and cultural control; 0.1 to insecticide residue determinations; 0.8 to biological control; 1.3 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for insect detection and control; and 0.7 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 6.1 professional man-years divided among subheadings as follows: Basic biology, physiology and nutrition 1.7; insecticidal and cultural control 3.8; insecticide residues 0.2; biological control 0.1; and varietal evaluation for insect resistance 0.3. Investigations are underway at State Stations to develop new information on the

seasonal history and habits of tobacco insects. State Stations are placing major emphasis upon insecticidal control including safe insecticides for transplant water, foliar sprays and dusts, soil systemics, and non-persistent chemicals. The effect of aging and curing tobacco processes on dissipation of pesticide residue is being investigated. Work on the selection and listing of new tobacco varieties for aphid, budworm and hornworm resistance is also in progress.

Industry and other organizations including tobacco growers contribute to the research effort on tobacco insects. Chemical companies make significant contribution on synthesis, analysis, formulation and primary screening of insecticides for general use, and several companies conduct limited field tests on insecticides against insects that attack tobacco. Several tobacco companies conduct extensive quality tests on the effect of insecticides on the flavor, aroma, and smoking quality of tobacco. Many tobacco growers cooperate with the Department and State Stations in providing tobacco acreage at no expense, in which insecticidal research may be conducted. Annual expenditures of industry are estimated to be equivalent to approximately 3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Hornworms and Budworms. Ecological studies on hornworm and budworm populations in the tobacco crop, which have been conducted in the Oxford, N.C. area during the past 10 years, were extended in 1961 to include areas near Florence, S.C., and Quincy, Fla. The accumulated data at Oxford indicated that the tobacco budworm, Heliothis virescens, is the major budworm during the growing season, but the corn earworm, H. zea, predominates after harvest. Budworms on tobacco are heavily attacked by natural enemies. The effect of natural enemies combined with the effect of insecticides allows very few budworms to mature on tobacco until after harvest, except when plants are not topped. Budworms in the seed capsules and in the flowers of untopped tobacco are not controlled by the natural enemies of insecticides. At Florence and Quincy, the seasonal pattern of populations was nearly the same as at Oxford. However, at Florence most of the tobacco fields were not topped until all of the plants had produced many flowers and large seed capsules. At Quincy large numbers of hornworms matured in certain fields on tobacco after harvest.

B. Insecticidal Control

1. Wireworms. In many areas of North Carolina and South Carolina the tobacco wireworm is resistant to chlorinated hydrocarbons that have been used successfully during the past 10 years for control. Furthermore, the southern potato wireworm, also a pest of tobacco, is moving into new areas of North Carolina and South Carolina and it is resistant to the same chlorinated hydrocarbons. Extensive field experiments at Florence, S.C., for the control of the tobacco wireworm and the southern potato wireworm have shown that both species are controlled with parathion or diazinon applied at the rate of 2-3 pounds per acre to tobacco soil in the fall or spring. Diazinon emulsion applied in the transplanting water was the most effective treatment tested with a mechanical transplanter. Some phytotoxicity was observed with most of the transplanting water treatments and further work is needed to determine an effective rate against both species of wireworms that will not cause stunting of plants.

C. Insecticide Residue Determinations

1. Arsenic residues. To determine the amount of arsenic absorbed by roots of tobacco plants and translocated to the leaves an experiment was conducted at Beltsville, Md., during three seasons, 1959-61. An isolated site selected for the experiment was sassafras sandy loam soil in an area in which no arsenical sprays or soil applications were made for at least 28 years.

Lead arsenate was mixed in the soil before planting in each of the three years to give various rates of arsenic as AS_2O_3 from 8 to 512 pounds per acre. The check plots were left untreated. All plots were mulched with sawdust immediately after setting the tobacco plants to avoid wind drift or rain spattering of soil. No insecticides were applied to the foliage during the growing period.

In the 1959 crop, arsenic content near 1 p.p.m. was determined in leaves from plants grown in untreated soil. Arsenic content ranging from 1.5 to 5.4 p.p.m. appeared in leaves of plants from the plots receiving 8 pounds of arsenic and 4.2 to 8.8 p.p.m. in those grown in the plots receiving 64 pounds of arsenic. In the treated plots, leaves from the lower and middle stem regions contained more arsenic than the top leaves. Only the middle leaves from 1960 and 1961 crops were analyzed, and no increase in arsenic absorption was present, even though the arsenic in the soil was increased 2 times in 1960 and 4 times in 1961 above the maximum dosage rates of 64 pounds used in the 1959 tests.

These experiments showed that a typical native soil contains measurable quantities of arsenic and that untreated tobacco plants absorb and translocate it to the leaves that are harvested. Additions of arsenic to the soil as lead arsenate is correlated with increases of arsenic content in the leaves. Adding 8 pounds of arsenic per acre to the soil slightly increased the arsenic in the harvested leaves. A 64-pound dosage was accompanied by an approximately doubled arsenic content over the 8-pound dosage. Analyses of leaves from plots receiving 128 pounds or 512 pounds of arsenic per acre indicated that arsenic absorption and translocation were not increased over the 64-pound dosage. The arsenic found in tobacco in this experiment can be interpreted as having been translocated from the soil since all practical precautions had been taken to avoid foliage contamination.

D. Insect Sterility, Attractants and Other New Approaches to Control

1. Tobacco Hornworm. At Oxford, N.C., male and female tobacco hornworm moths were treated with 1.0, 0.125, and 0.625 milligrams of aphoxide given orally in sugar water and then were mated with untreated moths of the opposite sex. At the lowest dosage, eggs hatched when laid by an untreated female mated with a treated male or by a treated female mated with an untreated male. At the middle dose, there was embryonic development in both cases but no hatch. At the highest dose, treated females did not mate; treated males mated but there was no embryonic development in the eggs laid by the untreated females with which they mated. Treatments did not affect the length of life of moths.

At Florence, S.C., crude extracts of the female hornworm moth secretions were attractive to the male moth. Since males were known to be attracted to females between 10:00 p.m. and 2:00 a.m., a unique procedure was used to obtain the attractive substance and to demonstrate its recovery. A number of virgin females, each confined in a small cage and inaccessible for actual copulation, were exposed during this period to male moths in a large outdoor cage. The tips of the abdomens of females that attracted one or more males were clipped and dropped immediately into ether. After 30 minutes a crude extract from this ether was absorbed on filter paper. Test male moths were attracted to such filter paper containing extract from 2 to 5 females. A similar extract of 220 attractive females was prepared by Division chemists late in the season and portions equivalent to the amount obtained from 2 and 8 females absorbed on filter paper were attractive to male moths. A portion of this material equivalent to the amount derived from 170 females has been retained by the chemists for fractionation studies. Earlier in the season extracts were made in ethyl alcohol from the

entire abdomen of two groups of virgin female moths that were not tested for attractancy before clipping. When samples of these extracts were exposed to male moths, the results were negative.

In experiments at Oxford, N.C., to develop methods for mass rearing of hornworms for use in population control studies, moths were released in a cage covering one-fourth acre of tobacco. More than 20,000 eggs were laid on the caged plants. The larvae fed on the growing plants until the last instar and were then brought indoors and allowed to feed on field-grown plants until they pupated. They pupated in sawdust in individual milk cartons or in sawdust spread on a floor. About 15,000 pupae were saved for later experiments. The tobacco in the outdoor cage can be used to produce one or two more broods annually.

2. Tobacco Budworm. In one sterilization experiment at Oxford, N.C., budworm pupae were treated with gamma rays at 2 and 5 kr. At the higher level, most of the moths that emerged were crippled and there was some crippling at the lower level. When treated moths were mated to untreated moths of the opposite sex, the females laid eggs but none hatched when treatment was at the 5 kr level. No eggs hatched from females mated to males treated at 2 kr but some females treated with this dose and mated to untreated males laid fertile eggs late in life.

E. Evaluation of Equipment for Insect Detection and Control

1. Light Traps. During the past 10-15 years, light traps have been used to study the seasonal activity and abundance of the tobacco hornworm moth. Small scale field tests to control this pest by placing a few light traps near tobacco fields were not successful in controlling the hornworm even though great numbers of moths were captured. Until the 1961 season, light traps had not been tested on a large scale basis, nor had the effect on the natural hornworm population been evaluated on the basis of release and recapture of marked moths.

From July 26 to August 18, 1961, the first large-area study was conducted with 14 light traps in a 2-square-mile area near Oxford, N.C. On August 18 the area was expanded to 25 square miles. Several thousand marked hornworm moths were released during the period of the test in each area. A summary of the findings is as follows: (1) the recapture of marked male tobacco hornworm moths in the 14 light traps increased from approximately 5 to 20% as the area of light-trap operation was expanded from 2 to 25 square miles, and 80% of the recaptures occurred within 2 days after the moths were released in either area; (2) traps located outside the

areas indicated that only about 5% of the marked released moths moved more than 5 miles; (3) catches of unmarked moths were higher in traps adjacent to tobacco fields than in traps located away from tobacco fields; (4) released moths dispersed rapidly in all directions and there were no indications that woods or other features of the landscape acted as barriers; (5) curves for the dispersion of tobacco hornworm males, based on the moths recaptured in these tests, indicated that 3 light traps per square mile should capture about 90% of the male moths and 30% of the females in the center of an area 12 miles in diameter. This information was used to design a proving ground to test population control measures.

To determine if light traps evenly dispersed over a large area could be used to reduce populations of hornworm moths or the fertility of females, 324 traps were erected in an area 12 miles in diameter near Oxford, N.C. by the Farm Electrification Branch, Agricultural Engineering Research Division, in the summer of 1962. In addition, 42 traps were placed in adjacent areas as a check. Intensive studies within the area were conducted by the entomologists. Preliminary data show a reduction in populations of moths of both species of hornworms and a lower percentage of mated females in the trapped area, but the effect on numbers of larvae on tobacco has not yet been determined. The field phase of the experiment will be continued until October 15, 1963.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Lawson, F. R., Rabb, R. L., and Guthrie, F. E. 1961. Studies of an integrated control system. Jour. Econ. Ent. 54(1): 93-97.

Insecticidal and Cultural Control

Allen, Norman, I., and Lawson, Francis. 1962. The tobacco budworm--how to control it. USDA Farmers' Bulletin No. 2174.

Agric. Res. Serv. and Fed. Ext. Serv. 1961. Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock - 1961 and 1962. USDA Agriculture Handbook No. 120.

Lawson, F. R., and Chamberlin, F. S. 1960. Aphids on tobacco - how to control them. USDA Leaflet No. 405 (Revised)

Biological Control

Allen, Norman, Kinard, W. S., and Creighton, C. S. 1961. Bacillus thuringiensis controls the tobacco budworm. Tobacco Science UP 58-62 and Tobacco 152(19): 20-24.

Creighton, C. S., Kinard, W. S., and Allen, Norman. 1961. Effectiveness of Bacillus thuringiensis and several chemical insecticides for control of budworms and hornworms on tobacco. Jour. Econ. Ent. 54(6): 1112-1114.

Insect Sterility, Attractants, and Other New Approaches to Control

Allen, Norman, Kinard, W. S., and Jacobson, Martin. 1962. Procedure used to recover a sex attractant for the male tobacco hornworm. Jour. Econ. Ent. 55(3): 347-351.

General

McMurtrey, J. E., Jr., and Chamberlin, F. S. 1961. Tobacco production. USDA Agricultural Information Bulletin No. 245.

AREA 11. SUGARCANE AND SUGAR BEET INSECTS

Problem. Insects and mites are major limiting factors in the production of sugar crops because of the direct damage they cause and the diseases they spread. The sugarcane borer alone caused a $5 million loss to the 1960 sugarcane crop. The use of available insecticides to control insects on sugarcane and sugar beets often leaves residues in the crop byproducts that makes them unsuitable for livestock feed. Safe, effective chemical methods are especially needed to control the sugarcane borer and the beet webworm. Sugarcane mosaic has become more important in recent years and information on insect vectors of this disease is needed. The beet yellows and the associated western yellows virus diseases of sugar beets have become a threat to the sugar beet industry and are particularly destructive in the Pacific Northwest. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. The development of suitable control measures is handicapped by lack of adequate knowledge of the identity and ecology of the insect vectors and plant reservoirs of the two viruses. For long-range solutions to the problems, further investigations should be undertaken on parasites and predators of sugar-crop pests, on varieties of sugarcane and sugar beets resistant to the insects involved, and on new insect control approaches such as the male-sterility technique or the development of attractants.

USDA PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugar beet directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway. Studies on sugarcane insects are conducted at Houma, La., and Canal Point, Fla., and on sugar beet insects at Mesa, Ariz., Twin Falls, Idaho, Logan, Utah, and Yakima, Wash. A small amount of work on sugar beet insects that had been in progress at Fort Collins, Colo., was transferred to Yakima, Wash., when the Fort Collins station was closed in January 1962.

The Federal scientific effort devoted to research in this area totals 7.2 professional man-years. Of this number, 0.7 man-year is devoted to basic biology, physiology and nutrition; 2.3 to insecticidal control; 0.8 to insecticide residue determinations;

0.9 to biological control; 0.4 to insect sterility, attractants and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.5 to varietal evaluation for insect resistance; 1.0 to insect vectors of diseases; and 0.5 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 4.0 professional man-years divided among subheading as follows: basic biology, physiology and nutrition 1.2; insecticidal and cultural control 1.5; biological control 0.1; insect sterility, attractants, and other new approaches to control 0.1; varietal evaluation for insect control 0.5; and insect vectors of diseases 0.6. The Louisiana Experiment Station is studying the life history and habits of the sugarcane borer and developing artificial diets to make possible the laboratory rearing of this pest. Studies on the use of insecticides and pathogens for control of the borer are also underway. Work on sugar beet insects is conducted in California, North Dakota and Washington.

Industry and other organizations including sugarcane and sugar beet growers contribute to the research effort in this area. Chemical companies conduct limited field tests of insecticides against insects that attack sugarcane or sugar beets in addition to the synthesis, analysis and formulation of new pesticides for general use. Some growers cooperate by supplying fields of sugarcane or sugar beets in which tests may be conducted. Estimated annual expenditures of industry, exclusive of grants and cooperative agreements to State and Federal stations are equivalent to approximately 2 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Sugarcane Insects. The annual harvesttime survey in 1961 to determine the sugarcane borer infestation in Louisiana showed 9% of the joints bored. This infestation may be compared with 13% in 1960, the low of 7% in 1951, and an average of 16% for the past 26-year period.

B. Insecticidal and Cultural Control

1. Sugarcane Insects. In the spring of 1962 recommendations for the use of insecticides to control the sugarcane borer were changed from 4 applications of 0.25 pound of endrin (12 pounds of 2% granules)

applied biweekly to 3 applications of 0.3 pound (15 pounds of 2% granules) applied at 3-week intervals. The percentage of infested plants required to justify treatment was increased from two to five.

Endrin emulsion concentrate applied at 0.4 pound of endrin per acre provided control equal to that obtained with 0.3 pound of endrin applied as 2% granules at a rate of 15 pounds per acre. There were some indications that the spray was less detrimental to beneficial ants than the granules. Guthion, Sevin, and EPN continued to show promise against the sugarcane borer.

Controlling the first-generation borer infestations did not reduce the need for subsequent insecticide applications against the second and third generations.

In a small-plot replicated test in Louisiana comparing 11 insecticides for control of small soil arthropods, chlordane at 2 pounds per acre was the best with a total yield increase over the check of 8.2 tons of cane. Other insecticides tested, their dosage rates, and increased yields of sugarcane were as follows: endosulfan, 2 pounds per acre, 7.4 tons per acre; phorate, 4 pounds, 6.2 tons; Bayer 22408, 4 pounds, 6.1 tons; Sevin, 4 pounds, 4.2 tons; Methyl Trithion, 4 pounds, 4.1 tons; Guthion, 2 pounds, 3.2 tons; diazinon, 2-1/2 pounds, 2.4 tons; Bayer 29493, 4 pounds, 2.4 tons; Zinophos, 4 pounds, 1.2 tons; and dimethoate, 4 pounds, 1.3 tons.

In tests at Canal Point, Fla., comparing 5 insecticides for the control of wireworms in sugarcane fields, phorate at 4 pounds per acre gave the best control and increased stand over 2-1/2 times that of the check.

2. Sugar Beet Insects. In Washington, field experiments were conducted to develop methods of preventing beet western yellows on sugar beets by control of aphid vectors. One experiment was designed to determine the most effective time of treatment by making applications of granular phorate to the foliage at 2-week intervals from May 3 to June 28. Results were inconclusive owing to low aphid populations, but fair control of thrips was obtained. In another experiment to determine the comparative effectiveness of various insecticides, Zinophos gave the best aphid control of nine granular insecticides applied to the foliage of small beets. Sprays of Di-syston, endosulfan, demeton, methyl demeton, schradan, phorate, and dimethoate all gave partial aphid control. Preplanting treatments of monogerm beet seed with phorate carbon dust at the rate of 0.8 ounces of phorate per acre were ineffective and may have reduced yield.

In Arizona, the effectiveness of endosulfan dust and foliar applications of phorate and Di-syston granules against the green peach aphid in sugar beets grown for seed were compared with the recommended BHC dust. Good control was obtained with the phorate granules but 29 days after treatment aphid populations were higher in plots treated with phorate than in the BHC or endosulfan plots.

In field experiments in Utah, V-C 13 granules at 1 pound of active ingredient per acre applied directly under the seed reduced the loss from the sugar beet root maggot 85% and increased the yield of sugar beets 2-1/2 tons per acre. Seed treatments of dieldrin, phorate, and aldrin were ineffective as were granules of heptachlor, phorate, aldrin, Trithion, Di-syston, ethion, or Zinophos when applied in the soil under the seed. Phorate granules at 1 to 2 pounds of phorate per acre mixed into the first 4 inches of top soil in a band along the seed row before planting controlled symphylans and increased the yield of sugar beets 3 tons per acre. Also, granules of phorate, parathion, Zinophos, and V-C 13, harrowed into the soil before planting at the rate of 3 pounds of the actual toxicant per acre, improved the stand of beets and increased the yield 1.6 tons per acre.

Field plot tests in Utah for the control of lygus bugs in sugar beets grown for seed showed that a dimethoate emulsion spray at 1 pound of dimethoate per acre plus 10% molasses applied to the crop in the early bolting stage gave control comparable to dimethoate emulsion alone or DDT emulsion plus WARF antiresistant compound sprays applied just before blooming. Each of these treatments resulted in the production of 83% viable seed as compared with 76% viable seed in the untreated check. If lygus can be controlled in the earlier stages of development, ground equipment can be used, whereas later applications must be made by airplane.

In Utah field plot tests in sugar beets with phorate granules as soil treatments in the seed row or as a seed treatment followed by two granular applications of phorate or Di-syston to the foliage of young plants reduced beet leafhopper populations and increased the yield of sugar beets 1.6 tons per acre.

In Idaho small plot tests for control of the beet leafhopper and prevention of curly top in sugar beets showed some increases in yield from Phosdrin and phorate sprays, although differences in curly top could not be measured. Extensive experiments were conducted in the greenhouse to develop methods of curly top prevention in sugar beets by vector control. Efforts were concentrated on slurry seed treatments with new systemic insecticides alone or in

combination with other insecticides or additives. Curly top susceptible varieties of sugar beets were used and tests consisted of caging curly top infective beet leafhoppers on plants grown from treated seed. Some of the combinations used in 38 tests gave good control of the beet leafhopper and reduced curly top. Further work is necessary since the best materials were too highly phytotoxic for commercial use.

Laboratory insecticide tests were conducted at Twin Falls, Idaho, against the beet webworm. Sprays of DDVP and Dylox gave the best control, but good results were also obtained with diazinon, naled, and dimethoate. Outbreaks of this webworm in beet fields are sporadic, and these screening tests are preliminary to field tests to be undertaken when there is an opportunity.

In Colorado, when granular phorate was applied to the foliage of sugar beets at the rate of 2 pounds per acre, there was a 91% reduction in populations of the sugar beet root aphid. One pound of phorate granules per acre was ineffective.

C. Insecticide Residue Determinations

At Yakima, Wash., samples of sugar beet tops and roots from experimental plantings of sugar beets in Washington, Idaho and Utah treated with insecticides were analyzed for residues as an essential part of the effort to develop methods of controlling insects on sugar beets without contaminating livestock feed.

D. Biological Control

1. Sugarcane Insects. Two parasites, Stenocranophilis quadratus and Anagrus armatus, introduced into Florida in 1959 for control of the West Indian sugarcane fulgorid, are now firmly established. S. quadratus, which parasitizes the adults is now found over the entire sugar-producing area of Florida where it destroys nearly 75% of the fulgorids. A. armatus was found as far as 10.5 miles from its nearest release point. Sugarcane borer parasitization by Agathis stigmaterus made in commercial fields at Fellsmere, Fla., averaged about 9%.

Parasitization of the sugarcane borer in Florida in 1961 by Lixophaga which was introduced from Trinidad, B. W. I., several years ago was 13%.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Insects. Studies continued in 1961 at Houma, La., on the effect of gamma radiation on sugarcane borer pupae indicated that any level of irradiation which results in complete male sterility may also severely reduce moth emergence.

Caged virgin female moths of the sugarcane borer failed to attract males from the field. Observations were made from dusk to midnight in both Florida and Louisiana.

F. Varietal Evaluation for Insect Resistance

1. Sugarcane Insects. Investigations were continued at Houma, La., to find sugarcane that can be used by plant breeders in developing new commercial varieties that are resistant to the borer and to determine the resistance of newer commercial promising unreleased varieties. Over 1/4 million borer eggs were produced in the Houma Laboratory for these and other studies. Eggs pinned to cane plants at time of second-, third-, and fourth-generation borers in the field resulted in a very heavy infestation, averaging over 65% joints bored as compared with a long-time average of only 17%.

Two hundred and thirty-two varieties of sugarcane were tested in Louisiana in the borer resistance nursery. One hundred and forty-four varieties had a lower infestation than check variety C. P. 36-105.

Of 19 agronomically promising unreleased varieties tested for resistance, varieties C. P. 53-1, L. 55-6, L. 56-7, L. 56-25, C. P. 57-1, C. P. 57-25, C. P. 57-108, C. P. 58-46, and C. P. 58-48 had a lower borer infestation and a higher yield per acre than the control variety C. P. 36-105. The most promising variety was C. P. 53-1 with three-fourths as much infestation and 2-1/2 times as much yield as the control.

Of 176 varieties assigned C. P. and L. numbers in 1961, only six were resistant and 10 moderately resistant to the borer. Twenty-two were susceptible and the rest moderately susceptible to average.

2. Sugar Beet Insects. In Colorado, small field plot tests against the sugar beet root aphid contained two varieties of sugar beets. One variety was susceptible to leaf-spot; the other was a commercial leaf-spot resistant variety. The leaf-spot resistant variety proved highly resistant to root aphids while the leaf-spot susceptible variety was attractive to the aphids. Untreated plots of the leaf-spot resistant variety contained only 3.4% as many aphids as the leaf-spot susceptible variety.

G. Insect Vectors of Diseases

1. Sugarcane Insects. Since many of the sugarcane varieties grown in Louisiana are susceptible to a recently identified new strain of mosaic, cooperative studies with pathologists of the Crops Research Division have been initiated to find new insect vectors of sugarcane mosaic. Two aphids, Amphorophora sonchi and Macrosiphum ambrosiae, both prevalent on sow thistle in sugarcane fields during the spring, have recently been identified as vectors of mosaic. In transmission experiments, 20% of 70 healthy test plants colonized with infected A. sonchi and 95% of 260 colonized with infected M. ambrosiae developed the disease. The mosaic transfers obtained with M. ambrosiae and the high populations of this aphid on its host plant in sugarcane fields during the season of peak secondary spread indicate that this is the most efficient and probably most important vector of sugarcane mosaic in Louisiana.

2. Sugar Beet Insects. In Arizona, winged green peach aphids migrating to sugar beets and lettuce were demonstrated to be carriers of beet yellows and beet western yellows viruses. Both of these viruses seriously affect the sugar beet seed crop. The aphids migrating to sugar beet seed fields infected 15% of the test beet plants with beet western yellows and 15% with both viruses. Those migrating to lettuce infected 10% of the test plants with beet western yellows and 15% with both viruses. Aphids migrating from a carrot field infected 10% of indicator plants with beet western yellows and 10% with both viruses. In no instance were any of the test plants infected with beet yellows virus alone. These tests indicate that beet western yellows is the predominate virus transmitted by the green peach aphid to the beet seed fields in Arizona. The beet western yellows virus is persistent, remains in the aphid as long as it lives, and can be carried great distances. On the contrary, the beet yellows virus is carried only a short distance by the aphid, is semi-persistent, and is lost in 72 hours. The tests were made by caging 20 seedling sugar beet plants in the greenhouse prior to transfer to the field where ten winged aphids were caught and put into each cage. After a 24-hour feeding period the aphids were killed with an insecticide and the plants held in the greenhouse for observation. Isolations and identifications of the viruses were made by a plant pathologist in the Crops Research Division.

In Arizona, continued studies on the effect of curly top transmitted by spring infestations of infective beet leafhoppers followed by infestations of virus yellows infective green peach aphids in these

experiments showed that spring infestations on curly top susceptible beets did not reduce the yield of seed. However, spring infestations of curly top infective beet leafhoppers followed by spring infestations of virus yellows infective green peach aphids caused a significant reduction in seed yield. None of the infestations affected the germination of seeds.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology and Nutrition

Charpentier, L. J., Mathes, Ralph, Long, W. H., and Concienne, E. J. 1961. Losses to the sugarcane borer in Louisiana. Sugar Bulletin 39(12):138-139.

Lieberman, F. V., Dicke, F. F., and Hills, O. A. 1961. Some Insect pests of important seed crops. USDA Yearbook. Seeds. p. 251-258.

Long, W. H., Hensley, S. D., Concienne, E. J., and McCormick, W. J. 1960. Insect conditions in Louisiana, Vol. 3, p. 14-16.

Insecticidal and Cultural Control

Charpentier, L. J. 1961. Effectiveness of insecticides against the rusty plum aphid and ants. Jour. Econ. Ent. 54(1):204.

Hensley, S. D., Long, W. H., McCormick, W. J., and Concienne, E. J. 1961. 1959 field tests with new insecticides for control of the sugarcane borer in Louisiana. Jour. Econ. Ent. 54(6):1153-54.

Hensley, S. D., Long, W. H., McCormick, W. J., and Concienne, E. J. 1961. Sugarcane borer populations in endrin treated fields. Sugar Bulletin 39(13):150-151.

Hensley, S. D., Long, W. H., Roddy, L. R., McCormick, W. J., and Concienne, E. J. 1961. Effects of insecticides on the predaceous arthropod fauna of Louisiana sugarcane fields. Jour. Econ. Ent. 54(1):146-147.

Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock for 1962. USDA Agriculture Handbook No. 120 (Revised)

Long, W. H., Hensley, S. D., Concienne, E. J., and McCormick, W. J. 1960. Ants found in Louisiana sugarcane fields. Insect Conditions in Louisiana. Vol. 3, p. 20-21.

Long, W. H., Hensley, S. D., Concienne, E. J., and McCormick, W. J. 1961. Field tests with new insecticides for sugarcane borer control in Louisiana in 1960. Jour. Econ. Ent. 54(6):1155-56.

Insect Vectors of Diseases

Charpentier, L. J. 1961. Sugarcane mosaic-vector studies in Louisiana. Sugarcane Bulletin. 39(19):222-224.

Hills, O. A., Gibson, K. E., and Rowchow, W. F. 1961. Insect viruses and seed crops. USDA Yearbook. Seeds. p. 258-264.

AREA 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are damaged by a great variety of insects and mites for which present control measures are inadequate. Their protection from insect damage requires more specific basic information on the identity, distribution, host-plant preferences, physical requirements, and biology of aphids, thrips, mites, beetles, and other pests that attack these plants, as a basis for the development of practical and effective control measures. Insecticidal and cultural controls are needed which will not adversely affect the growing plants, soil, or natural enemies of these pests. Spider mites and certain insects have developed strains that are resistant to recommended insecticides, further complicating the problem of chemical control. Studies are needed to determine the nature and cause of such resistance and how it can be overcome. The role of biological control agents in reducing losses caused by these insects and mites should be fully explored. Ornamental plants that are resistant to insect attack should be sought. There is need for studies to improve insect and mite control in greenhouses through controlled light and other environmental factors. Consideration should also be given to research on cultural practices combined with chemical control.

USDA PROGRAM

The Department has a program involving entomologists, chemists, physiologists, and insect pathologists engaged in both basic studies and applied research on growers' problems and on problems of concern to plant pest control and quarantine officials. Basic biology and nutrition studies at Beltsville, Md., Farmingdale, N. Y., and Sumner, Wash., and research on insecticidal control at Beltsville, Md., Moorestown, N. J., Farmingdale and Geneva, N.Y., and Sumner, Wash., were cooperative with the respective State Experiment Stations. Some of the work at Beltsville was cooperative with the Crops Research Division. Biological control studies at Beltsville, Md., Moorestown, N. J., and Geneva, N. Y., were cooperative with the respective State Experiment Stations as were studies on insect sterility, attractants, and other new approaches to control at Beltsville, Md., and Geneva, N. Y. Evaluation of equipment for insect detection and control was made at Beltsville, Md., Geneva and Farmingdale, N. Y., and Sumner, Wash., in cooperation with the Agricultural Engineering Research Division and respective State Experiment Stations. Research on insect vectors of diseases at Beltsville, Md., and Sumner, Wash., was carried on in cooperation with the Crops Research Division and the respective State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 6.8 professional man-years. Of this number, 0.5 is devoted to basic biology and nutrition; 1.7 to insecticidal control; 1.1 to biological control; 0.5 to insect sterility, attractants, and other new approaches to control; 0.4 to evaluation of equipment for insect detection and control; 0.6 to insect vectors of diseases; 1.3 to insect control treatments for commodities regulated by plant quarantine; and 0.7 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 15.9 professional man-years divided among subheadings as follows: Basic biology, physiology and nutrition 3.5; insecticidal and cultural control 9.2; biological control 2.2; insect sterility, attractants and other new approaches to control 0.1; evaluation of equipment for insect detection and control 0.2; varietal evaluation for insect resistance 0.1; and insect vectors of diseases 0.6. Connecticut, New York, New Jersey, Ohio, Illinois, Florida, Alabama, California, and Oregon are making important studies of ornamental and greenhouse crops. Connecticut, New York and Ohio conduct studies on the Japanese beetle and New York on the European chafer.

Industry and other organizations including growers also conduct research of interest and value on ornamental and greenhouse crops. A number of chemical companies supply materials for testing. Nurserymen, greenhouse operators, and park officials, country clubs, estate owners and others with large turf areas cooperate with the Department and State Experiment Stations by furnishing crops, land, and facilities for the evaluation of insect control treatments or programs. Estimated annual expenditures of industry are equivalent to approximately 5 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology and Nutrition

1. Insects of Ornamentals. Studies at Beltsville, Md., have shown that the two-spotted spider mite, Tetranychus telarius, increases in large numbers on all seedlings of poinsettia with a low latex content of the sap bred by the Crops Research Division for use as a cut flower. Spider mites caused complete defoliation and death of these seedlings, whereas the mites were unable to become established on the commercial cultivars of poinsettia with a high latex sap. This extreme susceptibility of an otherwise desirable new cultivar will limit its commercial use as a cut flower. The lewis mite,

Eotetranychus lewisi, under study at Sumner, Wash., infested poinsettia in several greenhouses in the East and Pacific Northwest in 1960. The 1960 infestations in the Pacific Northwest did not appear until late in the season (late November and December) and were limited to a very few plants. This spider mite is able to thrive on cultivars with high latex sap.

Results of the studies at Beltsville have shown that virgin females of the two-spotted spider mite and the mite, T. cinnabarinus, both mate freely with males of the opposite species and the crosses produce sterile hybrid females. The male offspring are haploid and thus similar to the female parent. The females were inseminated only once whether newly emerged from the quiescent stage or when 7 or more days old. Virgin females of either species exposed to equal numbers of males of both species tended to mate with their own kind. However, when two-spotted spider mite females were exposed to 3 times as many cinnabarinus males, 59% of the females produced hybrid offspring; and when 5 or 10 times as many cinnabarinus males were present, all females produced hybrids. Tests with large numbers of cinnabarinus males introduced for several weeks into an existing two-spotted spider mite population resulted in only 11% hybrid females among the offspring.

In continued studies at Beltsville on the effect of host plant nutrition on the fecundity of the two-spotted spider mite, Tetranychus telarius, adult females produced more progeny on lima bean plants supplied high levels of nitrogen than on plants supplied low levels. Mites also produced more progeny on young than on old leaf tissue irrespective to nitrogen supply. Mite fecundity increased concurrently with increases in nitrogen supply and absorption and decreases in phosphorus and total carbohydrate content of bean leaf tissue. More progeny were produced by mites on leaves left intact on plants than were produced by mites on discs excised from leaves of the same plants, even though more nitrogen and less phosphorus were found in detached leaf tissue.

A dipterous leaf miner, Liriomyza sp., that has seriously damaged chrysanthemum in many parts of the country during the past two years is distributed to greenhouses on cuttings grown in California or Florida. Preliminary studies at Beltsville on the biology of this insect indicate that adults of a given generation are present for 2 to 3 weeks; development from egg to pupation requires 8 days and the pupal period 10 - 11 days. Poor control in greenhouses has been largely due to improper timing of applications which permitted the larvae to complete development between sprays and pupate in the soil.

B. Insecticidal Control

1. Insects of Ornamentals. In greenhouse experiments at Sumner, Wash., dilute emulsion drenches of demeton, methyl demeton, and dimethoate applied to the soil of potted Easter lilies gave control of aphids for 9 to 16 weeks. Treatments were applied when the plants were about 8 inches in height, and aphid control extended through the blooming period. Phosphamidon and methyl demeton granules applied to Easter lily bulbs at potting time at the rate of 10 and 20 pounds of active ingredient per 6-inch acre protected the emerging plants from aphids for 5 to 8 weeks. Methyl demeton at the higher rate controlled aphids through the blooming period.

Greenhouse experiments at Beltsville, Md., revealed that all stages of resistant and non-resistant two-spotted spider mites and Telarius cinnabarinus were killed by dips of Pentac (ENT 25,718) at 0.5 pound of active ingredient per 100 gallons and by 1-day residues of Pentac on treated foliage. Older residues showed high mortality of adults after 2 or 3 days but hatching larvae developed to adults before they were killed. Pentac is unique in its visible action on spider mites; the adult female assumes a stance as in ovipositing, then slowly dies with an egg partly extruded. Sterile hybrid females from cinnabarinus and telarius crosses lived for about 2 weeks on Pentac residues. This is further evidence that the miticidal action involves the reproductive organs of the mature female. In commercial greenhouse tests two sprays of Pentac have destroyed resistant spider mite infestations and no further treatments were needed for 8 months.

The millipede, Oxidus gracilis, widely distributed in warmer parts of the United States and in greenhouses throughout the country, sometimes increases to large numbers and causes apprehension to greenhouse operators and home gardeners. Experiments in greenhouses at Baltimore, Md., showed that a soil drench containing ethion or American Cyanamid 18133 at the rate of 5 pounds per acre gave the most effective control for 7 weeks and dimethoate, also at 5 pounds per acre, controlled the millipedes for 4 weeks. Since the publication of these results, pest control operators have become interested in adopting one of these treatments in their control program.

In further tests at Beltsville for control of flower thrips in air-conditioned greenhouses heptachlor equalled dieldrin in effectiveness when added to the sump water of the cooling system at the rate of 1 pint of 18% emulsifiable concentrate per 50 gallons of water. Analyses of the sump water, to which heptachlor has been added showed that the heptachlor disappeared within 2 days and apparently adhered to the excelsior in the pads since it

effected control for about two weeks. Analyses of the greenhouse atmosphere by absorption of vapors in butyl alcohol indicated a heptachlor content of less than 1 part per 100 billion parts of air.

Greenhouse experiments against the two-spotted spider mite at Beltsville, Md., have shown that a 75% Polybutene H-35 emulsifiable concentrate at the rate of 1 gallon per 100 gallons of water gives partial control of resistant spider mites and of powdery mildew on roses but it is phytotoxic to rose foliage and leaves a sticky residue. The material destroys only active stages of spider mites. Many of those emerging from quiescents or eggs do not feed on sprayed foliage but move to the tender new growth where they cannot subsist or they accumulate on plant stakes and die. Survivors on unsprayed areas of older foliage renew the infestation.

Tedion did not prevent two-spotted spider mites from hatching but killed a high percentage of the hatching larvae. Females treated with Tedion produced a high percentage of nonviable eggs the first 24 hours. If exposed to Tedion residues for 24 hours or longer, they laid nonviable eggs for 2 days. Eggs of Tedion-resistant strains of mites hatched normally. Tedion did not affect the spermatozoa of male two-spotted spider mites and cinnabarinus since male mites on bean leaves dipped in Tedion and exposed to the residue for 24 hours produced normal female offspring when subsequently mated with virgin females.

At Farmingdale, N. Y., experiments with four varieties of chrysanthemum cuttings potted in soils treated with granular dimethoate, Di-syston, or phorate for the control of flower thrips indicated that dimethoate was phytotoxic at rates as low as 5 pounds per acre, whereas Di-syston and phorate were safe at 200 pounds but not at 400 pounds per acre. At the lowest rate, dimethoate caused chlorotic mottling, tip and edge burn of foliage. None of the soil treatments were effective against adult thrips, but phorate and dimethoate did reduce the number of nymphs developing in the flowers. Results also indicated that soil applications should be made before flower buds show color. Samples of thrips identified by the Insect Identification and Parasite Introduction Research Branch indicated the following order of abundance of species infesting chrysanthemum flowers: Frankliniella tritici, Mecrocophalathrips abdominalis, and Haplothrips facurei.

Research on insects attacking outdoor roses was conducted at Beltsville, Md. Malathion, DDT-lindane, Thiodan, dimethoate, Dibrom, and Isotox garden spray alone or with .1% Santomerse reduced aphid populations on outdoor roses and prevented reinfestation for approximately 3 weeks, after which DDT-lindane, Thiodan, and Dibrom sprayed plots became reinfested. Dimethoate, phorate

and phosphamidon sprays were promising for the control of flower thrips in outdoor roses resulting in the reduction of thrips for 3 days after application. None of the materials were satisfactory 7 days after application. In studies to evaluate soil drenches and fumigants for the control of free living plant parasitic nematodes on roses, V-C13 and Nemagon were ineffective. Ethylene dibromide gave nearly complete control and warrants further critical study to determine the range of effective doses and phytotoxicity effects.

In further tests against iris borers in 1961 at Beltsville, dimethoate and phorate at 1 pound per 100 gallons applied in early May when young larvae were feeding in the upper foliage gave no control; whereas almost complete kill of larger larvae was obtained by a second application three weeks later when the larvae were feeding in the sheaths where they could be reached by sprays or their vapors. The young larvae were protected from the first spray by exuding sap. The systemic action of these materials is not sufficient to control iris borers.

In Oregon, further field experiments conducted by the Sumner, Wash., laboratory with phorate and Di-syston granules applied over or under Easter lily bulbs at planting showed very satisfactory aphid control on plants throughout the 10-month growing season. The minimum rate to control aphids was 2 pounds of Di-syston or 4 pounds of phorate per 12,000 row-feet (per acre).

Easter lily bulbs from field-grown yearling bulbs were forced in several greenhouses to determine the effects of previous field treatments of phorate and Di-syston on their forcing performance. Bulbs treated with Di-syston or phorate in the field and then forced in the greenhouse produced better plants than those not treated. The treated plants had a higher bud count and brighter green foliage than untreated field-grown plants. A slight increase in height of plants from phorate field-treated bulbs over untreated was not enough to be detrimental. The height of the plants from Di-syston field-treated bulbs was similar to that of the untreated bulbs.

At Beltsville, Md., continuing experiments with new acaricides against spider mites on outdoor roses showed that phosphamidon (1.5 pints of 49% E.C.) and Kelthane (2 pounds of 18.5% W.P.) were equally effective throughout the season while Dibrom (.8 pint of 64.5% E.C.) was ineffective after early August and malathion gave no control. The surviving mites, transferred each year since 1950 from old to new plots, have become resistant to malathion.

Experiments were conducted at Beltsville to determine the effect of surfactants in a spray on the activity of an acaricide (Aramite) and a fungicide (Phaltan) for the control of spider mites and blackspot of roses, respectively. Acaricidal activity of Aramite was decreased by addition of Triton B-1956, Tween 20, Ortho Spreader Sticker, and Dupont Spreader Sticker but not by Santomerse. Fungicidal activity of Phaltan was also decreased by addition of Triton B-1956, Ortho Spray Sticker, Ortho Spreader Sticker, and Dupont Spreader Sticker but Santomerse and Tween 20 increased its effectiveness. In all cases, Phaltan gave better control of blackspot when Aramite was included. No phytotoxicity to rose plants resulted from Phaltan alone or when Ortho Spreader Sticker was included but severe injury developed when Triton B-1956 or Tween 20 were added. These studies on surfactants help to explain many cases of plant injury and poor control of mites and blackspot by commercial and amateur rose growers.

At Farmingdale, N. Y., gladiolus field experiments were continued for control of aphids with systemic insecticides to reduce the spread of cucumber mosaic. Treatments consisted of applications on and around the corms in the planting row of granular Di-syston and phorate, and liquid E.C. dimethoate at rates of 0.5 and 10 pounds per acre on three varieties of gladiolus. None of the treatments had any marked effect on the number of plants developing symptoms of cucumber mosaic. The insecticides caused an increase in incidence and severity of leaf-tip burn, especially at the higher rate of application. Use of insecticides on good quality growing stock resulted in increases in yield of flowers by 20 to 62% and of corms by 10 to 60%. Conversely, on poor quality stock of smaller corms, flower and corm yield were reduced. Expression of cucumber mosaic in flowers differed and weekly plantings of corms. April, May, June, and July plantings averaged, respectively, 29, 19, 13, and 44% of flowers with cucumber mosaic symptoms. A pronounced peak of aphid movement was not noted in 1961 as was evident during early August of 1960. Di-syston-and phorate-treated plots yielded fewer gladiolus thrips-injured flowers than dimethoate treated or untreated plots.

At Sumner, Wash., aldrin mixed in soil at a rate of 10 pounds per 6-inch acre in 1951 or 1954 protected narcissus bulbs from narcissus bulb fly attack in 1961, ten or seven years after application. Lindane or parathion smokes introduced into closed chambers were not completely effective against the tulip bulb aphid on iris bulbs. Exposed aphids were killed, but those concealed under husks were not. Sufficient aphids survived to develop to damaging numbers in normal storage conditions.

2. Japanese Beetle. Continued expansion of the area of infestation continually brings to light new problems concerning this insect and its control that require additional research. Work on this pest is conducted at Moorestown, N. J. In preliminary tests in 1960, Guthion, dimethoate, and phosphamidon were promising for the protection of foliage from attack by the beetle. In more extensive tests in 1961, when freshly applied, Guthion was less effective than DDT and dimethoate and phosphamidon were equally as effective as DDT. After weathering for 1 week, the protection afforded by residues of dimethoate and phosphamidon was reduced 30 to 50%. A spray containing 1 pound of either Sevin, dimethoate, or phosphamidon per 100 gallons was effective in protecting foliage for 5 to 7 days. A tung oil sticker showed promise for use to prolong the effectiveness of Sevin against adult beetles. Compound ENT-25,456, a synergist, failed to increase the effectiveness of Sevin. In preliminary tests in 1961, three emulsified polyvinyl acrylic esters were of no value in protecting foliage from attack by the beetle. In other preliminary tests neither Hercules 8717 (ENT-25,732) now Hercules 7522 (ENT-25,763) seemed to be as toxic to the beetle as DDT.

Raspberries and blueberries often ripen during the period of Japanese beetle abundance and attack. Sevin at 1 pound per 100 gallons applied when the beetles appeared and repeated 10-14 days later gave good protection.

The chlorinated hydrocarbon insecticides - DDT, toxaphene, aldrin, chlordane, dieldrin, and heptachlor - cannot be applied to pastures used for grazing dairy cattle or animals being finished for slaughter because of the possible contamination of the milk or meat, but forage treated with Sevin may be grazed or harvested without this hazard. Preliminary laboratory tests indicated that to control Japanese beetle grubs in pastures 10 pounds of Sevin per acre would be needed at a soil temperature of 80° F. and 50 pounds per acre at a soil temperature of 60°. When applied and left on the surface of the soil at a temperature of 85° in the laboratory, there was no loss of the insecticide during an exposure of 2 weeks, as determined by bioassay with Japanese beetle grubs, but Sevin may be less persistent when exposed to sun, wind, and rain. The preliminary study of Sevin was sufficiently encouraging to justify further investigation of the chemical for the control of the grubs.

Lack of precise chemical methods for determining small amounts of combinations of insecticides in nursery soils has prompted research to develop suitable bioassay techniques. A practical method of assay for the chlorinated hydrocarbon insecticides in soils that can be used at any time of the year developed with Drosophila as

the test insect, has recently been accepted for practical use by the Plant Pest Control Division. The mortality of the flies has been correlated with that of newly-hatched grubs. When 50% or more of the flies exposed to soil under standardized conditions are killed, the toxicity in the soil is adequate to prevent the development of newly-hatched Japanese beetle grubs. The sensitivity of this bioassay procedure with a light mineral soil ranged from 0.004 p.p.m. of aldrin to 1.24 p.p.m. of DDT.

Concentration-mortality standards, requiring exposures of 24 hours, have been developed with Drosophila to evaluate the toxocity in soil treated with aldrin, chlordane, dieldrin, and heptachlor. The maximum amount of insecticide equivalent to the toxicity that can be determined accurately from those standards is at the 80% mortality level where the equivalent amount of insecticide is about one-fifth of the chlordane, one-seventh of the dieldrin, one-twentieth of the heptachlor, and one-thirtieth of the aldrin recommended for control of the grubs. The dilution of soil with more concentrated residues was not satisfactory when the dilution was more than 1.9 or a different soil was used as the diluent. Concentration-mortality curves at the 50% mortality level have been developed for determining the insecticidal equivalent of the more concentrated residues of aldrin, chlordane, dieldrin, and heptachlor. With these concentration-exposure standards it is now possible to determine directly 10 pounds of chlordane, and 3 pounds of aldrin or dieldrin per acre, the recommended amounts for an initial application. Drosophila, however, is not a suitable test insect for evaluating residues of lead arsenate and Sevin in soils. Mortality after an exposure of 52 hours to an application of 80 pounds of Sevin per acre was only 36%.

A study was made, in connection with Japanese beetle control, on the effect of exposure of granular formulations of aldrin, chlordane, DDT, dieldrin, and heptachlor on the soil surface. Plots were treated in May at the rate approved for nursery treatment for Japanese beetle quarantine and soil samples were taken weekly. After 4 weeks only about 10% of the aldrin and heptachlor, 20% of the chlordane, 40% of the dieldrin, and 60% of the DDT was recovered by chemical analysis.

3. European Chafer. The search was continued at Geneva, N. Y., for new insecticides for use against the chafer grubs in soil. Hercules 7522H (ENT-25,763) and Hercules 8717 (ENT-25,732), Di-syston and Bayer 29493 were practically non-toxic but Telodrin (ENT-25,545) had about 8 times the toxicity of dieldrin to the grubs. In comparative tests heptachlor epoxide was somewhat less toxic to the grubs than heptachlor.

C. Biological Control

1. Insects of Ornamentals. At Beltsville, Md., two predaceous mites, Phytoseiulus persimilis, procured from Prof. G. Dosse of West Germany, and a Typhlodromus species from a Beltsville strain, were tested on treated plants in the laboratory for tolerance to pesticide residues. All three of these species prey on injurious spider mites and therefore are beneficial. Neither species was affected by residues of aldrin, dieldrin, endrin, Chlorobenzilate, ovex, Tedion, Aramite, Kelthane, captan, maneb, Phaltan, or zineb. The Typhlodromus mite also tolerated DDT residue but the Phytoseiulus mite was killed by 1 to 3-day-old residues. The Typhlodromus mite has probably acquired resistance to DDT since DDT has been used repeatedly for several years to control this species in greenhouse colonies of the two-spotted spider mite. Both species of mites were killed by residues of the following pesticides for the indicated days - chlordane, heptachlor, Genite 923, lindane, and methoxychlor (3 days); Thiodan, Chlorbenside, TEPP, demeton, and Guthion (7 days); diazinon (9 days); Sevin (12 days); ethion, EPN, malathion, and parathion (14 days).

The Phytoseiulus mites have been released in a commercial greenhouse where resistant two-spotted spider mites were present on roses. The chemicals that are more hazardous to the predaceous species will not be used in the general insect and disease control program. These mites have survived and are building up under commercial greenhouse conditions in this integrated biological-chemical control program.

2. Japanese Beetle. Recent increases in Japanese beetle populations in areas where milky disease and other natural control agents have held infestation in check for some years have caused concern regarding the continuing effectiveness of the milky disease. Investigations on biological control of the beetle were conducted at Moorestown, N. J. Surveys of trouble spots indicate that, in general, the natural control agents, including milky disease, are functioning normally at undisturbed sites. In the fall of 1960 an assay of the soil from 29 sites in Delaware, Maryland, New Jersey, New York, Pennsylvania, Virginia, and the District of Columbia, where the milky disease bacteria had been known to be present, and from 1 site where the organism causing the blue disease of Japanese beetle grubs had been colonized, indicated that the density of bacterial spores was adequate to depress the grub population to a low level at 16 sites, but was inadequate at 14 sites, at 4 of which other pathogens were sufficiently numerous to effect adequate control. The blue disease organism was not found established at the site where it had been colonized.

A further study was made in 1961 of the status of the milky disease bacteria in Burlington County, N. J., the county where the Japanese beetle was first discovered in 1916 and where milky disease was colonized in 1940. Assays of soil from 20 colonized and 13 uncolonized sites revealed the presence of milky disease spores at all of them, but at only one in sufficient numbers to prevent an increase in the grub population. However, other bacteria and fungi were also active in most of the sites. Based on these assays, it appears that in about two-fifths of the area in Burlington County, the complex of pathogens in the soil is not sufficiently numerous to cause much of a reduction in the grub population; in another two-fifths of the area, they are numerous enough to cause a significant reduction, but possibly not sufficient for control. In the remaining one-fifth of the area, the pathogens are sufficiently numerous to prevent the build-up of the grub population from year to year. This situation is an important factor in the localized upsurges of the beetle. However, with these upsurges the complex of pathogens in the soil should become progressively more numerous and more effective in reducing subsequent grub populations.

The Moorestown, N. J., laboratory has cooperated with the Plant Pest Control Division in various experiments with the use of the milky disease in large-scale Japanese beetle control. Twelve formulations of milky disease spores, prepared in granular form for airplane application, seemed to contain the expected concentration of viable spores. Airplane applications of the milky disease spores in granular formulation in Georgia, North Carolina, and Ohio have given definite establishment, although the build-up was rather slow. At some locations, other pathogens increased progressively in effectiveness until they appear now to have a major role in controlling the beetle.

Efforts to develop a practical method for producing spores of the milky disease bacteria is the subject of research by the Fermentation Laboratory of the Northern Utilization Research and Development Division and industry. Bioassay of samples submitted by the Fermentation Laboratory and by industry failed to reveal one of practical value. Efforts to develop such a method are being continued.

3. European Chafer. Work on this insect was carried on at Geneva, N. Y. Additional parasites of the chafer received from Europe were colonized in New York. It has yet to be demonstrated that any introduced parasite species has become established. The search was continued in New York for a strain of the milky disease bacteria with greater virulence to chafer grubs than the

DeBryne strain of Bacillus popilliae. The spores of B. popilliae from Cyclocephala sp., Phyllophaga fusca, and P. hirticula were not very infectious to either Japanese beetle grubs or chafer grubs; those from P. anxia were more pathogenic to chafer grubs than to Japanese beetle grubs. Spores of the regular strain of B. lentimorbus had a high pathogenicity to Japanese beetle grubs but not to chafer grubs. However, spores of both species of bacteria when grown in the blood of Japanese beetle grubs tended to be more infectious to those grubs than to chafer grubs; the situation was reversed when the spores were produced in the blood of chafer grubs. Of all of the strains considered, the DeBryne strain was the most infectious to chafer grubs. In an attempt to increase the virulence of that strain, blood from infected grubs was used to inoculate healthy grubs; when these became infected, their blood was used to inoculate other healthy grubs. During the 7 years of this study, this procedure has been repeated 50 times. The virulence of the pathogen tended to increase progressively through the tenth transfer, but since then there has been no indication of a significant change in its infectiousness.

Temperature is an important factor in the development of infection by the milky disease bacteria among chafer grubs. When third-instar grubs were exposed for 4 weeks in soil containing 1 billion spores per kilogram, practically all of the grubs at 80° F., became infected, about one-half at 70°, and less than one-fourth at 60°.

In view of the difficulty in producing spores of Bacillus popilliae on artificial media and the ease with which vegetative cells of the pathogen can be produced, there has been considerable interest in the survival of the vegetative cells in soil. Less than one-fifth of the chafer grubs exposed to the vegetative cells became infected; infection developed among all of the grubs in the spore-inoculated soil, indicating that the vegetative cells survive for only a short time in soil.

Spores of Bacillus popilliae harvested from chafer grubs 2, 7, 10, 13, and 17 days after the initial development of gross symptoms of infection were used to inoculate brain heart infusion agar, and to inject into healthy grubs. The percentage of the spores growing on the artificial medium tended to increase with the time elapsing since the initial development of gross symptoms of infection. However, there was no relationship between the growth of the spores on the medium and the development of infection among the grubs. Spores incapable of growth on the medium were infectious.

In further tests with the Maryland strain of Bacillus lentimorbus, B. euloomarahae, and B. friourgensis, the first two bacteria were definitely pathogenic to both Japanese beetle and European chafer grubs, but the third had a very low virulence. When the grubs were introduced into soil containing spores of B. lentimorbus and B. euloomarahae no infection developed among them.

Assays made in the fall of 1961 of the soil from 32 1-acre plots, one-third of the total, where spores of Bacillus popilliae had been applied as a spot treatment to 96 1-acre plots in pastures in 1954 in a cooperative program with the Department of Entomology of Cornell University, and assays of soil from adjacent areas, showed only limited increase and spread of the pathogen, partly because of the low population level of the chafer since 1954 in the area. B. popilliae was dominant in the treated area and B. lentimorbus in the adjoining untreated areas. In 1961 assays of small-scale plots also initiated in 1954, the results showed that the pathogen is established and spreading slowly in an irregular pattern.

Exposure of spores of Bacillus popilliae to gamma rays from a cobalt 60 source to provide an irradiation dosage of 5,600 rads had little effect on the growth of the spores on artificial medium and it seemed to increase their infectivity when the spores were injected into grubs or used to inoculate soil; a dosage of 100,000 rads reduced the growth of the spores on artificial media, but seemed to have no effect on their infectivity to grubs. A dosage of 1,000,000 rads killed practically all of the spores.

D. Insect Sterility, Attractants, and Other New Approaches

1. Insects of Ornamentals. At Beltsville, Md., studies were initiated to develop methods of producing sterility in mites by irradiation. Untreated female spider mites mated with males irradiated in the deutonymph stage at doses of 30 or 40 kr deposited the normal number of eggs, but approximately one-half of the eggs developed to haploid males of the parental mother. The other half were not viable. Female mites irradiated at the same stage of growth and rate produced few or no eggs and the eggs which were deposited failed to hatch.

2. European Chafer. In tests at Geneva, N.Y. of the attractiveness of fluorescent lamps radiating energy from 2537 angstroms to 6450 angstroms, the blacklight lamp with a peak emission of 3650 angstroms was, by far, the most attractive. The chafer was attracted to only a limited extent to lamps with shorter or longer wave lengths. In competitive and isolated comparisons the effectiveness of traps with a range of blacklight lamps increased

progressively with the wattage of the lamps, using 4-to-30-watt lamps. About $\frac{3}{4}$ of the chafers are captured by such traps from dusk to midnight and none after dawn. In a 3-year study of the relationship between the effectiveness of blacklight traps and the proximity to trees in which chafers were congregating, over 80% of the chafers were captured in traps placed beneath the canopy of the trees. As distance between trap and tree increased, the less effective the trap was in capturing chafers.

There is need to know the longevity of the attractiveness of blacklight fluorescent lamps to the chafer. The fluoren output of 15-watt lamps that had been burned 4,500 hours, as determined by the ARS Agricultural Engineering Research Division at Purdue University, was only about $\frac{1}{2}$ that of the unburned lamps. However, no differences in the attractiveness of the different groups of lamps could be established in New York. The experimental results demonstrated that a blacklight lamp should be effective in attracting chafers for $4\frac{1}{2}$ scouting seasons; it probably would be effective for 6 seasons.

The most effective chemically-baited trap for capturing chafers is one painted red and baited with 3:1 mixture of Java citronella oil and eugenol. In 1959 and 1960 chemically-baited traps and 15-watt blacklight lamps tested in competition in an open field from which chafers were emerging, captured about the same number of chafers. However, chemically-baited traps are most effective in an open field and blacklight traps in the vicinity of a large tree. Blacklight traps under trees are more efficient than the best-known chemical lure in a preferred location in attracting European chafers. Battery-operated traps appear to be a little less attractive to the chafer than traps operated on regular AC current. Three hundred and sixty-three compounds tested as lures for the chafer in New York, resulted in the discovery of only two compounds, butyl sorbate (ENT-5,089) and isopentyl sorbate (ENT-21,776) that were as attractive as the standard bait (Java citronella oil - eugenol). The attractiveness of butyl sorbate was enhanced by diluting it with ethyl alcohol or by decreasing the exposure of the wick in the bait bottle from 1 inch to 1/8 inch. When traps baited with the standard bait and with butyl sorbate were compared in an area where there was a fair population of Japanese beetle, those with the standard bait were responsible for 97% of the Japanese beetles captured. In surveying for the chafer in Japanese beetle areas, it would therefore be of advantage to use butyl sorbate as the lure in chemically-baited traps, in order to reduce the catch of Japanese beetles.

The chafer was not attracted to extracts of unmated male and female chafers.

E. Evaluation of Equipment for Insect Detection and Control

1. European Chafer. It was determined that a blacklight trap for capturing chafers should have the following elements: (1) a 15-watt fluorescent blacklight (BL) lamp, (2) a 4-vaned baffle, (3) a funnel with a $\frac{3}{4}$-inch opening to exclude large insects from the receptacle, and (4) a receptacle with a 1/6-inch mesh screen bottom to permit the escape of small insects. Increasing the size of the funnel so that the baffle was set into instead of being flush with it did not increase the effectiveness of the trap. Inclusion of a baffle more than doubled the effectiveness of the trap in capturing chafers. The material used in constructing the baffles did not seem to be an important factor.

The color of blacklight traps had no significant influence on the number of chafers captured.

The blacklight lamp is highly attractive to many nocturnal insects. The accumulation of these insects in the receptacle of a trap makes more difficult the determination of the number of chafers captured. Tests in New York in 1959 and in 1960 demonstrated that hawk moths, giant water bugs, and other large insects could be largely excluded from the receptacle without changing significantly the number of chafers captured by reducing the orifice of the funnel to a diameter of 3/8 inch. Most of the small unwanted insects escaped from the receptacle when the solid metal bottom was replaced with 1/6-inch mesh wire cloth, or the lower half of the receptacle was replaced with this wire cloth.

F. Insect Vectors of Diseases

1. Insects of Ornamentals. At Beltsville, Md., studies on the prevention of the spread of cucumber mosaic virus in gladiolus showed that granular Cynem, Di-syston, and phorate applied to the soil below corms at planting time did not affect aphids caged on flower buds. In subsequent greenhouse tests, green peach and cabbage aphids survived for 3 days or longer on young foliage of plants grown in soil containing these systemic insecticides at rates up to 50 pounds per acre. These studies show that these insecticides are not translocated in gladiolus in sufficient quantity to control the aphid vectors and thus prevent the spread of cucumber mosaic virus infection in gladiolus.

Gladiolus growers are experiencing serious losses from cucumber mosaic virus infection. A spot survey by the Beltsville laboratory in 1960 of gladiolus fields in northeastern United States revealed more field spread in New Jersey, New York, and Ohio where gladiolus were grown near aphid-infested vegetable crops than in grain-growing

areas of Indiana. Also the virus spread was lower in early planted gladiolus than in late season plantings.

Tobacco ringspot virus was transmitted from gladiolus to gladiolus on tools in harvesting the flowers and also by aphids.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Japanese Beetle. There is a continuing need for improved treatments for nursery stock and farm products to eliminate infestations of the Japanese beetle to permit their movement without danger of spreading the pest. An emulsified alcoholic solution of heptachlor was found equal to a similar formulation of aldrin for killing Japanese beetle grubs in the soil of potted plants without injury to the plants.

The use of certain chlorinated hydrocarbon insecticides is authorized for the elimination of Japanese beetle grubs in potting soil. The exposure specified at a minimum temperature of 60° F. has been 30 days for aldrin, chlordane, dieldrin, or heptachlor, and 60 days for DDT or toxaphene. It was found that third-instar grubs accumulated a fatal dose of aldrin, chlordane, dieldrin, or heptachlor within 1 week at this temperature, of toxaphene within 2 weeks, and of DDT within 4 weeks, showing that the exposure required for aldrin, chlordane, dieldrin, or heptachlor can be safely reduced to 14 days and that for DDT or toxaphene to 28 days.

Chlorinated hydrocarbon insecticides are authorized for the treatment of soil to eliminate Japanese beetle grubs in blocks of plants in commercial nurseries subject to the restrictions of the Japanese beetle quarantine. These insecticides are applied at such rates that the treatments are usually effective in eliminating newly-hatched grubs during the following 4 or 5 years. Since the minimum effective dosages of these insecticides vary according to the nature of the soil, it is necessary to know how much insecticide is actually needed in a particular soil type to establish definitely when more insecticide should be applied to continue a plot in a certified status. In 1960, using Drosophila as a test insect, a practical procedure was developed for determining at any time of the year the minimum amounts of any of these insecticides needed in any soil. However, most of the nursery stock is grown in mineral soils containing a moderate amount of organic matter. It was determined that such soils might be continued in a certified status as long as the upper 3 inches of soil contained at least 8 pounds of DDT, 7 pounds of toxaphene, 1 pound of chlordane, 0.8 pound of dieldrin, or 0.2 pound of heptachlor or aldrin per acre.

Chemical analyses are complex when two or more insecticides are in a soil; they do not necessarily establish whether the toxicity in a soil is adequate or inadequate. Using adult Drosophila and third-instar Japanese beetle grubs as test insects, bioassays were made of the soil from (A) 39 plots where one or more residual insecticides had been applied to eliminate Japanese beetle grubs, (B) 34 plots where various insecticides had been sprayed on foliage to control other insects, but no insecticide had been applied to the soil to control grubs, and (C) 16 plots where both soil treatment and foliar sprays had been applied. About the same appraisal of toxicity was made with both test insects. The toxicity was adequate to eliminate newly-hatched grubs in 30 of the plots in group A, 20 of those in group B, and 14 of those in group C. It is of interest that in group B, where only foliar sprays had been applied, sufficient toxicity had been built up in some of the plots to eliminate grubs.

Bioassays were made later of 18 additional samples of soil from commercial nurseries. The toxicity in the soils treated with aldrin, chlordane, or heptachlor was definitely in excess of what was needed to kill grubs. The toxicity in the soil of plots where foliar sprays with lead arsenate, DDT, lindane, parathion, and malathion had been applied was not adequate to eliminate grubs. There was little toxicity in the soil of plots where foliar sprays containing rotenone, pyrethrum, parathion, and malathion had been applied.

The study of the toxicity of binary mixtures of the chlorinated hydrocarbon insecticides in soil, begun in 1959, was continued using Drosophila as the test insect. There appeared to be a synergistic action in many of the mixtures. In others, the toxicity did not differ significantly from what was expected. Since there was no antagonism between any of these chlorinated hydrocarbon insecticides, a soil containing a residue of one of them may be retreated with one of the others without loss of toxicity due to any unfavorable reaction between the insecticides. In related studies of the inactivation of chlorinated hydrocarbon insecticides in various soils, using the Drosophila bioassay technique, results showed that more consideration needs to be given to the nature of the soil to insure adequate quantities of insecticide to insure elimination of Japanese beetle grubs.

Requirements for the certification of the soil in a nursery plot are that the insecticides applied be mixed with the upper 3 inches of soil immediately. There was a question of how long these insecticides could be left on the surface of the ground before significant losses occurred. Bioassays with Drosophila showed that exposures of one week on the surface of the soil caused the following losses

in effectiveness for the various materials: toxaphene, little loss; dieldrin, 6 to 26%; DDT, about 15%; chlordane, 32 to 50%; aldrin, 68 to 72%; and heptachlor, 62 to 86%. It was concluded that no change should be made in the practice of cultivating chlorinated hydrocarbon insecticides into the soil immediately after application.

2. European Chafer. Emulsifiable aldrin (formulation 515) and emulsifiable heptachlor (formulation 544) diluted with water 1:800 were authorized as an immersion or a pour-on treatment to eliminate chafer grubs in the soil of potted plants, providing the temperature was above 60° F. and the exposure was 2 weeks, as a result of research completed in 1960 and 1961. In a further study exposures of under 2 weeks were not always effective in killing all of the grubs but there was no advantage in prolonging the exposure for more than 2 weeks. Studies of the exposure time needed to eliminate chafer grubs from potting soils following treatment with aldrin, dieldrin, heptachlor and chlordane showed that at 60° F. the grubs accumulated a toxic dose within one week, permitting a reduction in the recommended exposure period for quarantine purposes from 70 days to 14 days. Emulsifiable heptachlor at a dilution of 1:800 killed all of the grubs in a mineral soil, but to obtain the same level of effectiveness in Junius peat the concentration had to be increased to 1:400, and in Atlantic peat to 1:50.

Immersion of balled and burlapped masses of infested soil balls into emulsifiable aldrin or heptachlor resulted in complete mortality of third instar chafer grubs but injection of emulsifiable aldrin into the soil of potted plants did not do so. The mortality of grubs progressed at about the same rate in a mineral and two peat soils in the immersion tests. Addition of subeffective amounts of ethylene dibromide did not enhance the rate of insecticidal action of aldrin or heptachlor in the immersion tests.

In a study of the speed of insecticidal action of dieldrin against the third-instar chafer grubs in different soils in New York, 100% mortality was obtained in Farmington loam in 6 weeks. At that time the average mortality in two mucks was 88% and in five peats 73%. The coarseness of the peat did not seem to be a factor. It appeared from the increase in dosage required to obtain the same level of mortality in peat as in loam soils that the peat had inactivated 87% of the chlordane, 86% of the dieldrin, and 92% of the lindane. When Junius peat was added to Farmington loam, the speed of insecticidal action of insecticide mixtures decreased progressively with the increment in the amount of peat. In a study of dilute dusts and more concentrated granular formulations

of chlordane and dieldrin for the treatment of potting soil to eliminate chafer grubs, the speed of insecticidal action was usually faster with 1 and 1.5% dusts than with the 5 and 10% granular formulations. However, all formulations affected the grubs sufficiently during a 2-week exposure to assure their death. Temperature was an important factor affecting the speed of insecticidal action of soil insecticides to the European chafer in New York. A drop in temperature from 80° to 70° F. required a 4-fold increase in the amounts of chlordane or dieldrin to kill 50% of the grubs in two weeks and a drop from 80° to 60° F. required about a 10-fold increase. None of the grubs pupated when the soil contained 1 pound of chlordane or 0.5 pound of dieldrin per acre and only 1% of the grubs pupated when there was 0.5 pound of chlordane or 0.25 pound of dieldrin per 3-inch acre.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology, and Nutrition

Doucette, C. F. 1962. The lewis mite, Eotetranychus lewisi, on greenhouse poinsettia. Jour. Econ. Ent. 55(1):139-40.
Henneberry, T. J. 1962. The effect of plant nutrition on the fecundity of two strains of two-spotted spider mite. Jour. Econ. Ent. 55(1):134-7.

Insecticidal and Cultural Control

Anderson, M. S., Lakin, H. W., Beeson, K. C., Smith, F. F., and Thacker, E. 1961. Selenium in agriculture. USDA AH-200.
Doucette, C. F. 1960. Controlling aphids on Easter lily. Florists' Review 126(3266):37.
Doucette, C. F. 1961. Systemic insecticides for control of aphids on field-grown Easter lily. Jour. Econ. Ent. 54(3):595-97.
Fleming, W. E. 1960. Soil insecticides. In methods of testing chemicals on insects. 11:p 47-75. Burgess Pub. Co., Minneapolis, Minn.
Fleming, W. E. 1960. The Japanese beetle: how to control it. USDA FB 2151.
Fleming, W. E., Parker, L. B., Maines, W. W., Plasket, E. L., and McCabe, P. J. 1962. Bioassay of soils containing residues of chlorinated hydrocarbon insecticides, with special reference to control of Japanese beetle grubs. USDA Tech. Bull. 1266.
Henneberry, T. J., Taylor, E. A., Smith, F. F., Boswell, A. L., and McClellan, W. D. 1960. Pesticide combinations for protection of roses from spider mites and blackspot. Amer. Rose Mag., p 12-14.
Henneberry, T. J., Taylor, E. A., Smith, F. F., and Boswell, A. L. 1960. Comparative acaricidal activity of Tedion, Ovex, and Chlorbenside against two strains of two-spotted spider mite. Jour. Econ. Ent. 53(5):841-43.
Henneberry, T. J., Taylor, E. A., Smith, F. F., and Boswell, A. L. 1961. The effect of Tedion on the eggs and larvae of three strains of the two-spotted spider mite, Tetranychus telarius. Jour. Econ. Ent. 54(1):168-69.
Henneberry, T. J., and Taylor, E. A. 1961. Control of millipedes in greenhouse soil. Jour. Econ. Ent. 54(1):197-98.
Henneberry, T. J., Taylor, E. A., and Smith, F. F. 1961. Foliage and soil treatments for the control of flower thrips on outdoor roses. Jour. Econ. Ent. 54(2):233-35.
Henneberry, T. J., Taylor, E. A., Smith, F. F., Boswell, A. L., and Travis, R. V. 1961. Combination acaricide-fungicide sprays on outdoor roses. Jour. Econ. Ent. 54(3):420-22.

Henneberry, T. J., Taylor, E. A., and Palmer, J. G. 1961. The effect of acaricide-fungicide combination sprays on two-spotted spider mite populations, blackspot control and winter injury to roses. Jour. Econ. Ent. 54(4):659-61.

Henneberry, T. J., Taylor, E. A., Travis, R. V., and Smith, F. F. 1961. Control of spider mites on roses with miticide-fungicide combination sprays. Amer. Rose Mag. XVI (11):12-13.

Henneberry, T. J., and Taylor, E. A. 1961. The effect of clean culture and early spring acaricide treatments on overwintering spider mite populations in outdoor rose plots. Jour. Econ. Ent. 54(6):1255-56.

Palmer, J. G., and Henneberry, T. J. 1960. Blackspot and powdery mildew of roses. Amer. Hort. Mag. 39(2):108-10.

Palmer, J. G., Semeniuk, P., and Henneberry, T. J. 1960. Effects of Phaltan and Acti-dione -- separately and in combination upon powdery mildew and plants of blackspot resistant Rosa Wichuraiana. Amer. Rose. Mag., p 8-26.

Palmer, J. G., Henneberry, T. J., and Taylor, E. A. 1961. Evaluation of three fungicides. Amer. Rose Mag. 16(4):9, 27-28.

Palmer, J. G., and Henneberry, T. J. 1961. Influences of rose blackspot by Phaltan. Pl. Dis. Rep. 45, No. 8.

Smith, F. F. 1960. Greenhouse insect control. Ill. State Fl. Assoc. Bull. 207, p 5-6, and Penna. Flower Growers' Bull. 111.

Smith, F. F. 1960. Resistance of greenhouse spider mites to acaricides. Misc. Pub. Ent. Soc. Am. 2(1):5-12.

Smith, F. F., and Palmer, J. G. 1961. Pest and disease control of outdoor roses. The Amer. Rose Ann. 46, p 91-97.

Tashiro, H. 1962. Ethylene dibromide for control of the European chafer in soils accompanying nursery plants. USDA ARS 33-71.

Travis, R. V., Henneberry, T. J., and Smith, F. F. 1961. Fungicide spray combinations for the control of rose blackspot. Amer. Rose Mag. 16(3):6-7.

USDA Agricultural Handbook AH-120. 1962. Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock, 1962 season. (Rev. 1962).

Wester, R. E., Smith, F. F. 1961. Safe application of granular organic phosphate insecticides. Agric. Chem. 16(1):59, 75.

Biological Control

Fleming, W. E. 1961. Milky disease for control of Japanese beetle grubs. USDA Leaflet 500.

Insect Vectors of Diseases

Brierley, P., and Smith, F. F. 1960. Transmission of tobacco ring-spot virus on tools during harvesting flowers and corms of gladiolus. Pl. Dis. Rep. 44(7):463-64.

Brierley, P., and Smith, F. F. 1960. Cucumber mosaic virus on Nandina domestica. Phytopath. 50(8): 569 (Abstract).

Johnson, G. V., and Bing, A. 1961. Tests with systemic insecticides for the control of the cucumber mosaic virus in gladiolus. Gladio Grams No. 48, p. 2-4.

Smith, F. F. 1961. Insect vectors of cucumber mosaic in gladiolus. Gladio Grams No. 48, p. 10-13.

Smith, F. F., and Brierley, P. 1961. Ornamental plants as virus reservoirs. Jour. Econ. Ent. 54(3): 506-08.

AREA 13. BEEF CATTLE, HORSE, AND SWINE INSECTS

Problem. Insects and ticks irritate and torment livestock throughout the year in all parts of the United States and cause serious losses. These pests reduce weight gains, lower the quality of meat and hides, and spread numerous animal diseases. Livestock losses directly attributable to insects and ticks are estimated to exceed $300 million annually. Practical but not adequate control methods have been developed for lice, screw-worms, ticks, bots, grubs, and other insects, but satisfactory methods of protecting cattle from horse flies, deer flies, stable flies, mosquitoes, and the newly introduced face fly remain an unsolved problem. The development of insecticides for use on beef cattle, horses, and swine has been hampered because certain insects have become resistant to various insecticides, and because harmful residues have been found in meat following the application of certain materials. Safe, effective, nonresidue-forming insecticides and repellents are required. Urgently needed are economical and long-lasting insecticides or repellents for range cattle to protect them against vicious biting flies. Safer, cheaper, and more effective systemic insecticides and more efficient means of administration are needed to combat grubs and bots in cattle and horses. New approaches to control, including radiation and chemosterilants, should be explored to determine their feasibility as practical control methods. Efforts also need to be made to find and evaluate insect pathogens, parasites, and predators for controlling certain livestock pests. Expanded basic studies on the biology and physiology of these pests are needed to find weak links in their life cycles that will serve as a basis for the development of more effective and safer methods of control. Research also is urgently needed on the role of insects in the spread of diseases of livestock.

USDA PROGRAM

The Department has a continuing, long-term program involving basic and applied research on insects and ticks which affect the health and productivity of beef cattle, horses, and swine. Studies are conducted on the biology, physiology, genetics, and nutrition of the screw-worm, stable fly, horn fly, house fly, mosquitoes and other pests; on the nature of insect resistance to insecticides; and on absorption, metabolism and excretion of insecticides by insects feeding on or in animals; the effects of irradiation and chemosterilants on insects; insect attractants and repellents; and other new approaches to control. Research is concerned with the development of more effective contact and systemic insecticides and protective treatments for the

control of livestock pests. Studies are conducted to determine the occurrence of residues in tissues of animals treated with insecticides. Minor consideration is given to the development of sanitation and management procedures and biological control methods, including parasites and predators, for controlling the face fly, stable fly and several other pests. Emphasis is also given to the development of insect sterility, attractants and various other noninsecticidal approaches to control. Studies are conducted in cooperation with the Agricultural Engineering and Animal Husbandry Research Divisions to evaluate various kinds of traps and devices for estimating and controlling natural insect populations, and improved or special equipment for the application of insecticides to animals. Limited research is conducted on the role of insects and ticks as vectors of livestock diseases, with particular emphasis on bovine anaplasmosis.

The Federal scientific effort devoted to research in this area totals 16.3 professional man-years. Of this number, 6.1 is devoted to basic biology, physiology and nutrition; 3.9 to insecticidal and sanitation control; 2.0 to insecticide residue determinations; 0.2 to biological control; 2.0 to insect sterility, attractants and other new approaches to control; 0.2 to the evaluation of equipment; 0.8 to insect vectors of diseases; and 1.1 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 11.1 professional man-years divided among subheadings as follows: Basic biology, physiology and nutrition 2.2; insecticidal and sanitation control 5.9; insecticide residues 0.7; biological control 0.8; insect sterility, attractants and other new approaches to control 0.6; evaluation of equipment 0.3; and insect vectors of diseases 0.6.

Industry, especially chemical companies, and other organizations are engaged in research on the formulation and evaluation of insecticides for the control of livestock pests. Industry also cooperates with Federal and State workers in developing information on residues resulting from the use of promising insecticides in connection with label registration. Estimated annual expenditures by industry are equivalent to approximately 10 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

1. Mosquitoes. Studies on the biology of mosquitoes were conducted in Oregon, Nevada and California. At Reno, Nev., studies were continued

in cooperation with the Soil and Water Conservation Research Division on the biology and control of mosquitoes in relation to land and water management practices. In 1961 water supplies throughout the State were low; in March the reservoirs were nearly empty and water supplies ranged from about 15 to 50% of normal.

In Nevada further studies on the ranges of pH and salinity in the breeding areas of Aedes niphadopsis and A. campestris confirmed and slightly extended the ranges observed previously. No mosquito breeding was found in waters with total soluble salts as high as 67,200 p.p.m. Water of breeding sites for Culex erythrothorax ranged from pH 6.8 to 9.1; total soluble salts ranged from 237 to 7,320 p.p.m. Studies confirmed observations in 1960 that certain abandoned mines furnish excellent overwintering habitats for mosquitoes, especially Culex tarsalis.

Population emergence for Culex erythrothorax was 1 1/2 to 2 months earlier in southern Nevada than in northern and central areas of the State. The larvae overwinter in Nevada. In two breeding areas, heavy ice and destruction of emergent vegetation by migratory ducks and geese reduced the larval population noted the previous November by about 97%. In other areas, a gradual build-up of pupae was observed in April and pupae predominated in late April and early May. A colony of this species had been established in the laboratory. Aedes campestris, believed to be a univoltine species (one brood per year) produced a large brood in June following heavy rainfall. Normally this species breeds only in the spring. Biting adults of Anopheles freeborni were noted in early February in southern Nevada; some Culex tarsalis activity occurred in late March in the valleys. Only a few Aedes niphadopsis could be induced to feed on humans although this species has been reported a vicious biter of livestock and humans. Breeding of Aedes increpitus began as early as February 10 at an elevation of 4,500 feet; at 6,300 to 6,700 feet breeding began in mid- to late March. In the spring a survey of 74 suspected mosquito breeding sites showed Aedes niphadopsis to be the dominant species in 65% of the sites, whereas Aedes campestris was more abundant in 28% of the sites. Aedes dorsalis predominated in only 7% of the samples. Ten species of mosquitoes were autogenic (capable of oviposition without a blood meal): Aedes campestris, A. communis, A. dorsalis, A. melanimon, A. niphadopsis, A. nigromaculis, A. schizopinax, Culex erythrothorax, C. tarsalis, and Culiseta incidens. Only Aedes communis and Culex tarsalis had previously been reported autogenic.

Surveys were continued on biting arthropods of the Humboldt River Basin of Nevada in connection with a major study of water resources being carried out cooperatively between the U. S. Departments of Agriculture and Interior, the University of Nevada, and the Nevada

State Department of Conservation and Natural Resources. For the third successive year, waterflow was only about one-fourth of normal and very few breeding areas received water. Only light breeding of Aedes melanimon, A. vexans, Culex tarsalis, and Culiseta inornata was observed. Very few biting adult mosquitoes were noted. Tabanids (horse and deer flies) and black flies were also negligible.

At Fresno, Calif., research on control of mosquitoes in relation to irrigation practices was conducted in cooperation with the California Bureau of Vector Control. Studies showed that dairy drains are sites of heavy breeding of Culex quinquefasciatus through November and into early December. The breeding in such locations probably contributes heavily to the overwintering adult population of this species. Autogeny (ability to lay eggs without a prior blood meal) was observed in Culiseta inornata and C. incidens but not in other species.

At Corvallis, Ore., studies on flight movements of Culex tarsalis indicated they move from their resting stations about sunset and return about sunrise. The instinct of tarsalis to oviposit in low sites is stronger than the instinct for oviposition in favorable waters. Female tarsalis mate only once whereas males mate several times. Laboratory studies indicated that 4th instar Aedes sierrensis larvae enter diapause from about the last week in September through the third week in December; diapause can be induced in the laboratory through manipulations of the photoperiod and broken by constantly increasing day lengths.

Studies were continued in Oregon on the status of insecticide resistance in mosquitoes. Tests showed that DDT-resistant Culex tarsalis larvae breeding on irrigated farms and in log ponds were also resistant to closely related compounds, but not to dieldrin or lindane. Further spread of resistance in Culex mosquitoes was indicated when Culex peus showed some apparent resistance to DDT and tarsalis, for the first time, showed some resistance to malathion. Studies on the physiology of resistance showed malathion-resistant larvae of C. tarsalis to be more efficient in regulating salt (chloride) uptake than susceptible larvae during exposure to malathion. Resistant and susceptible larvae take up similar amounts of chloride when exposed to 1% sodium chloride alone. Exposure to 1% sodium chloride resulted in an increase of oxygen consumption in susceptible and malathion-resistant larvae, but chloride had no measurable effect on cholinesterase inhibition or accumulation of malaoxon, the principal breakdown product of malathion in mosquitoes. Studies of the insect enzyme systems cholinesterase and aliesterase, led to the development of synergists for organophosphorus insecticides. Several tris-substituted derivatives of phosphoric acid overcame the resistance of tarsalis larvae to malathion, increasing its toxicity 100-fold to a resistant strain.

2. Stable Fly. Studies were continued at Lincoln, Neb., on the biology of stable flies. Immature stages of the stable fly overwinter in protected situations. None survived in environments subject to frequent freezing and thawing. The first adult flies appeared on June 1 and gradually increased in numbers through June. Peak populations occurred during July and August.

Efforts were continued in Nebraska to induce resistance to DDT in stable flies. After selection with topical applications of 0.005-0.075% DDT for 34 generations, no resistance was apparent and the colony was discontinued. However, when 36 p.p.m. of DDT was placed in the larval medium, 3-fold resistance was indicated in 6 generations. After 11 generations (1 year), the colony tolerated 500 p.p.m. in the media and some larvae survived 625 p.p.m. Resistance was about 14-fold.

3. Face Fly. In Nebraska, adults of the face fly hibernating in homes became active in February. Collected females contained well developed eggs but did not oviposit in the laboratory. Adults were first observed on cattle at Lincoln on May 14 and by late June herds were lightly infested. High populations persisted from early July until cool weather.

After considerable investigation of nutritional requirements, a thriving colony of the face fly was developed under laboratory conditions. The adult diet consisted of cattle feces, citrated blood, milk, dimalt and bee pollen. Larvae were reared in cattle feces and pupated in a mixture of sand and vermiculite. The life cycle (egg to egg) was 14 days at 82° F. and 28 days at 70°.

4. Horn Fly. Studies on the biology of the horn fly were continued in Texas and Oregon. In Texas intensive spraying was employed to eradicate horn flies at one location during the late fall, whereas flies persisted in other locations until early December. In the spring flies reappeared at untreated locations nearly 4 weeks earlier than at the treated location. The flies overwintered as diapausing pupae and prepupae. In Oregon, the horn fly overwintered as pupae in cattle droppings but house flies and stable flies failed to survive. Adult horn flies began emerging from overwintering pupae on May 17 and emergence was complete by June 24. Emergence ranged from 0.8 to 14.8% in exposed droppings and from 3 to 61% in those protected by screen cages.

In laboratory studies in Oregon occasional eggs of the horn fly hatched at a constant temperature of 52° F. and the larvae developed to pupae, but no adults emerged from them. Adults also did not emerge from

1-day old pupae reared at 80° F. and then kept at a constant temperature of 52° for 3 months but when returned to 80°,20% produced adults in 5 days. When 5-day-old pupae were transferred from 80° to 52° F., adult emergence occurred between 7 and 23 days, whereas at 80° it was complete in 1 to 3 days.

In Texas a laboratory colony of the horn fly has been developed and maintained for 10 generations without contact with a bovine host. The adult diet consists of bovine blood, ground beef juice and an antibiotic to prevent spoilage. The optimum temperature for survival and reproduction is 90° F. Larvae are reared in feces of cattle fed alfalfa hay. The feces of cattle fed sorghum or prairie grass proved unsatisfactory as larval media.

5. Screw-worm. Investigations on the screw-worm were conducted at Kerrville, Tex. The sexual development and behavior and genetics of the screw-worm fly were studied. Dissections showed that egg development was synchronous in all ovarioles. The exact stage of development of the oocyte and the nurse cells and the cytological condition of the nucleus were determined for various ages of females. Males began mating when 2 days old but were not vigorous in mating until 4 days of age.

The number of adults in holding cages and mating activity had pronounced effects on longevity. Optimum longevity occurred when not over 100 adults were confined in 12 x 12 x 20-inch cages. Adults also lived longer when the sexes were kept separate and when the male to female ratio was reduced. Excess mating by males and harassment of females by males reduced longevity.

Efforts were made to develop a genetically distinct strain of screw-worm fly. In examining many thousands of adults from scores of strains, a black mutant male was discovered. Selected matings resulted in the development of a homozygous black strain. When this strain proved inferior to normal strains in longevity and mating vigor, new genes were introduced by mating black females to normal blue males. After inbreeding for several generations, the black strain was equal to normal strains in longevity and mating vigor. Several additional new strains have been developed from larvae and adults, including one in which the scutellum is fused laterally to the scutum. Linkage studies with "black" and "interrupted" marker strains showed that these genes are sex-linked on the "X" chromosome. Crosses of these strains did not produce the expected number of black males, and females homozygous for the "interrupted" gene did not survive as well as the heterozygotes.

Efforts to formulate a completely synthetic larval rearing medium have proved unsuccessful so far, but progress has been made in developing a modification of the standard ground meat-blood medium. Screw-worm larvae reared for 48 hours on the standard medium consisting of 50% horse meat, 30% bovine plasma and 20% water, were successfully transferred and completed development in media in which 50, 75, 87.5 and 100% of the horse meat had been replaced with fish flour. The substitution of the fish flour reduced production costs to as low as 8.7¢ per thousand pupae, compared with 21.4¢ for the standard medium. Weights of the larvae ranged from 73.0 to 69.6 mg. for the 50 to 87.5% substitutions, as compared with 74.6 mg. for the standard. The 100% substitutions yielded larvae that weighed only 60.2 mg., but the adults lived slightly longer than those produced on the standard medium. In cage tests the small males and normal-sized males mated about equally as well with normal-sized females.

Intensive studies were made on the effects of irradiation on the sexual development, mating ability and longevity of the screw-worm. A dosage of 5,000 r completely sterilized both sexes. No oviposition resulted from matings of irradiated males and females and normal males and irradiated females, wereas matings of irradiated males and normal females resulted in normal oviposition but none of the eggs hatched. Female flies 0 to 0.4 hours old were more sensitive to irradiation than 5-day old pupae. A dosage of 2,000 r reduced ovarian growth by 50% in young females but had no significant effect on ovarian growth in females irradiated as 5-day old pupae. Irradiation had little or no effect on ovarian growth in females over 48 hours old. However, oocytes in 4- to 5-day old females were damaged more by irradiation than those in 3-day old flies. No difference was noted in the longevity of 5-, 6-, and 7-day old flies irradiated with 7,500 r in one, two, or three exposures. The number of dominant lethals and longevity of adults were unchanged regardless of whether 5-day old pupae were irradiated with a single dose or equal fractions at intervals of 8 and 24 hours.

There was no consistent difference in the effects of 1,000 and 5,000 r administered as a single dose or two equal doses. Female flies 3, 4, and 5 days old differed greatly in radiation sensitivity but dominant lethals were induced in the oocytes of all ages. In additional tests with 5-day old pupae, which have only oogonial cells, the number of eggs deposited by females decreased as the radiation dose increased, indicating that damage to some cells eliminated them from the germ line and that they were not rapidly replaced.

Additional studies on the effects of irradiation on 4-, 5-, 6- and 7-day old screw-worm pupae showed decreased longevity of adults with increased dosage. All stages showed lower mortality at 2,800 r than at higher dosages.

When female screw-worms were irradiated as 5-day old pupae in a well-aerated container, a dose of 5,000 r produced 99% sterility. When the same dose was given in an atmosphere of carbon dioxide, less than 50% sterility resulted. However, irradiation in an atmosphere of 50% air and 50% CO_2 produced a greater effect than in air alone. These results suggest that the irradiation capacity of the present Cobalt-60 sources could be increased by 38% by irradiating with 5,000 r in 50% air-50% CO_2. For this synergistic effect to be shown, it is necessary that the insects be held in the CO_2-air mixture for at least 30 minutes prior to, as well as during, irradiation. It should be a simple engineering job to modify the currently used procedures for such irradiation.

Studies were conducted on the absorption, distribution, metabolism, and excretion of P^{32} metepa (chemosterilant). Metepa was absorbed faster and excreted more slowly by the stable fly than the screw-worm fly. This may account for the fact that the sterilizing dose of metepa is much less for the stable fly than for the screw-worm fly.

Field cage studies showed that mature screw-worm larvae released on soil at 73° F. entered the ground in 3-4 minutes and pupated in 24 hours. Peak emergence of adults occurred 12 days later between 5:00 and 8:00 a.m. Adults did not feed or exhibit mating activity until 4 days old. Adult survival was high for 9 days but very few adults were alive after 22 days. In similar releases when soil temperatures were 51° F., few larvae entered the soil and although many were alive after 1 week, none had pupated.

Work was conducted on the dispersal and behavior of marked released adult screw-worm flies. The first night after release from 0.4 to 10% of the marked flies were recovered within 25 yards of the release point. Recoveries decreased on successive nights. In some tests none apparently moved over 400 yards, whereas in others, dispersion was rapid, as far as 1 mile in 45 minutes. Over 90% of the adults were found resting near the tips of leafless twigs within 4-5 feet of the ground.

6. House Fly. The following report on these insects covers work conducted at Corvallis, Ore.

DDT-resistance in house flies was attributable to the ability of the flies to dehydrochlorinate the insecticide. The mechanism of resistance in house flies to the carbamates was due to aliesterase activity, the same as for the organophosphates.

P^{32} memepa (chemosterilant) was rapidly absorbed and metabolized by house flies and mice. Almost complete degradation occurred in 24 hours with phosphoric acid being the major metabolic product.

Irradiation of resistant flies with 1,000 r did not alter their susceptibility to insecticides or esterase activity. Radiated females mated with normal males produced normal numbers of eggs but only 45% were fertile.

Further studies were conducted with colonies of normal and parathion-resistant flies that had been irradiated as pupae with 600 r for 7 generations. Only about 25% of the eggs hatched from matings of irradiated males and females of either colony. No changes in either esterase activity or insecticide susceptibility were apparent.

Certain synergists greatly increased the toxicity of malathion to resistant strains of house flies. The synergists, simple tris-substituted derivatives of phosphoric acid, completely overcame high levels of resistance when used at 1:1 or higher ratios of synergist to insecticide. The most effective materials increased the toxicity of malathion from 36- to 40-fold against resistant house flies. Only about a 2-fold increase was indicated against susceptible strains of house flies. The relative ability of several of these materials to synergize malathion against resistant house flies was directly related to the inhibitory effect of the synergists on aliesterase activity. Strong synergists for malathion inhibited aliesterase activity at concentrations as low as 10^{-5} M, while related nonsynergistic materials failed to inhibit the ali-esterase at concentrations up to 10^{-2} M. The synergists may actually inhibit the mutant aliesterase present in all organophosphate-resistant fly strains.

House flies treated with the synergist tributyl phosphorotrithioate and then treated with either parathion or paraoxon accumulated greater quantities of paraoxon than did flies treated with the toxicants only. This was true with both susceptible and parathion-resistant strains of flies. Measurements of the inhibition of thoracic cholinesterase activity provided a far better picture of the toxic action of organophosphates than did measurements of head cholinesterase.

Selection of a house fly colony with Isolan produced a strain with 3-fold resistance in 14 generations. At the same time, levels of esterase activity to methyl butyrate declined to 40% of the original level in flies of the selected strain. This same phenomenon occurs when house flies are selected with organophosphates, indicating that the same mechanism is responsible for resistance to both classes of insecticides.

House flies were capable of dispersing a distance of at least 5 miles in 24-48 hours.

7. Cattle Grubs. Research was initiated in Texas and Oregon to determine the nutrition requirements of cattle grub larvae and to develop

an artificial medium for rearing larvae under laboratory conditions. Second and third stage larvae have been successfully reared to maturity in serum in shell vials, but adult emergence from the pupae was quite low. Efforts to develop a suitable medium and techniques for rearing first stage larvae have proved unsuccessful so far.

8. Horse Flies and Deer Flies. Studies were continued in Mississippi on the biology of tabanids. The earliest species, Tabanus lasiophthalmus, appeared on March 31, reached a peak by late April, and disappeared by late May. T. vittiger schwardti, the most prevalent species, appeared April 5, was abundant from mid-May until early July and small numbers persisted until cool weather. T. fuscicostatus appeared May 11, reached a peak in June and disappeared by early September. Other species of lesser importance and dates of their occurrence were as follows: T. proximus, June 8 to September 7; T. lineola, April 26 to Oct. 5; T. americanus, May 24 to August 17; and Chrysops flavida, May 11 to Oct. 19. A total of 18 species was collected during the season. Several species of adult flies were collected and fed in confinement on cattle. Females of T. proximus and T. vittiger schwardti produced egg masses in captivity and the eggs hatched in 7 and 4 days, respectively.

9. Lice. Studies were conducted in Oregon to determine the factors involved in the decrease of cattle louse infestations during the spring and summer and the increase of populations during the fall and winter. The free cattle harbored very few lice after shedding their winter coat in the spring, but when they were restrained heavy infestations developed within a month. When released the cattle licked and rubbed themselves constantly for several days, causing a precipitious decline in louse populations. During the winter the heavy coats on the animals apparently minimized the effects of rubbing and licking and as a result high louse populations persisted throughout the winter.

10. Ticks. Work in Texas indicated that irradiation at the rate of 1,000 r had no effect on the molting of unfed or engorged nymphal lone star ticks. However, a dose of 2,500 r prevented molting of unfed and 1-day engorged ticks and only 3% of those engorged 1 week molted to adults. Exposure of newly molted nymphs to 1,000 r completely sterilized the males but not the females.

B. Insecticidal and Sanitation Control

1. Mosquitoes. In Oregon studies were continued to find repellents for protecting animals from attacks by mosquitoes. None of 200 compounds screened in spot tests on cattle showed promise. Other

screening tests were conducted with a number of new insecticides against larvae and adults of Culex tarsalis. Three of the materials gave 100% kills of larvae at a concentration of only 0.025 p.p.m. In spray tests seven materials were 2 to 9 times more toxic to adult mosquitoes than malathion (standard) and two of these compared favorably with parathion.

2. Stable Fly. In Texas 447 compounds were screened in spot tests on cattle for repellency and toxicity against the stable fly. Of these materials 9 were Class IV repellents at 5%, 8 were Class IV repellents at 10%, 3 were Class IV toxicants at 0.5% and 2 were Class IV toxicants at 5%. The outstanding repellents were diamyl tartrate, 3-ethyl 2,4-octanediol, benzyl acetoacetate, piperonyl chrysanthemumate and Hercules AC-6432. Three other materials were slightly less effective. The most effective toxicants were Geigy G-27365 and Shell SD-2359.

Comparisons were made of the toxicities of various insecticides to stable flies. The LD-50's in µg/fly for the materials tested were as follows: Ronnel, 0.015; methoxychlor, 0.057; DDT, 0.072; DDT and WARF, 0.091; toxaphene, 0.17; diazinon, 0.021; pyrethrins, 0.021 to 0.028; and pyrethrins and piperonyl butoxide, 0.017.

Large cage tests were conducted on calves to compare the residual effectiveness of a number of new insecticides and methoxychlor (standard). Ruelene, Baytex, Bayer 22408 and Sevin were effective for 3 to 5 days against stable flies but were less effective than methoxychlor.

Extensive tests with pyrethrum showed that ultra-violet light was the most important factor in its rapid loss of effectiveness, although infrared was also deleterious. Wave lengths in the range of 2600-4000A caused the greatest loss in effectiveness of pyrethrum. Several hydroquinone antioxidants and lanolin prolonged the toxicity of pyrethrum about two-fold under irradiation. Several phosphoric acid derivatives increased the effectiveness of malathion against stable flies but had no effect on Sevin or methoxychlor.

Of 111 compounds tested as systemics in Texas, only 8 caused mortality of stable flies feeding on guinea pigs. Hercules 7522-H and Rhodia RP-9895 were effective orally at 50 and 100 mg./kg. The other six materials were effective orally at doses of 10 to 50 mg./kg. but their chemical names are confidential. Thirty Class IV repellents were administered orally to guinea pigs to determine if they would prevent feeding by stable flies. All were ineffective.

3. Face Fly. In Nebraska, a number of insecticides were administered to cattle in feed in order to determine levels necessary to prevent fly

breeding in the feces. Daily doses of V-C 13 at 4 mg./kg., Cygon at 5 mg./kg. and Co-ral at 10 mg./kg. gave 100% control of breeding but seven other materials were only partially effective at the doses tested. Sprays of methoxychlor, malathion, Delnav and synergized pyrethrins provided little or no control of this pest. Halters treated with DDVP, Dipterex and methoxychlor reduced fly populations but did not provide satisfactory control. Effective control of breeding was obtained by feeding Co-ral at 0.5 mg./kg. and ronnel at 7.8 mg./kg. daily but adult populations on the cattle remained high, presumably because of migration from adjacent farms. Weekly applications of 0.08 lb/acre of Co-ral on pastures prevented fly breeding in droppings of cattle but here again no effect on adult populations was apparent.

4. Horn Fly. In Texas tests were conducted on calves in large cages to compare the residual effectiveness of a number of new insecticides and methoxychlor (standard). Ruelene, Baytex, Bayer 22408 and Sevin were effective for 7-10 days as compared with 17 days for methoxychlor. Extensive field tests were conducted in Texas and Mississippi to compare several old and promising new insecticides for the control of horn flies on cattle. In Texas effective control was obtained with 0.25% sprays of GC-4072 for 15-21 days, with 0.06% diazinon for 8-12 days, and with 0.5% Dilan, Dipterex and methoxychlor for about 2 weeks. In Mississippi control was obtained for 11-14 days with 0.1 to 0.25% sprays of Shell 4294; for 7-10 days with 0.25% Sevin and with 0.1% Baytex; for 3 weeks with 0.5% Dilan and methoxychlor; and for 10-30 days with 0.25 to 0.5% Shell 4294. In season-long tests, effective control of horn flies was maintained with 4-5 sprayings of 0.25% Shell 4294, with seven sprayings of 0.1%, and with two applications of 2% in oil to backrubbers. Effective control was also maintained with mist sprays of 1% Shell 4294 applied weekly and of 0.05% pyrethrins and 0.01% DDVP applied daily.

Extensive tests were conducted to determine the effectiveness of low level feeding of insecticides in controlling horn flies. In Texas daily dosages of 7.8 mg./kg. of ronnel prevented horn fly breeding in droppings and reduced adult populations to a sub-annoying level within a week. Free choice feeding by cattle on ronnel salt blocks also provided very good control. Other effective materials and dosages were as follows: Co-ral, 0.5 mg./kg.; Bayer 22408, 1 mg./kg.; GC-4072, Baytex, Bayer 34727 and Stauffer R-1504, 2.5 mg./kg.; and Bayer 37342, American Cyanamid 38023 and Bayer 37341, 10 mg./kg. In Mississippi free-choice feeding on ronnel salt blocks and daily feeding at 4 mg./kg. prevented breeding in droppings and adult fly populations decreased significantly.

5. Screw-worm. Research was continued in Texas to develop more effective insecticides for controlling screw-worms affecting livestock. One hundred thirty-one new compounds were screened for

systemic action by administering them orally and subcutaneously (SC) at several dosages to guinea pigs artifically infested with screw-worms. Ten of the materials showed systemic action in one or both types of administration. The active compounds and minimum effective dosages in mg./kg. were as follows: Stauffer N-2310, Stauffer N-2599 and Stauffer N-3055, 25 mg. orally and 50 mg. SC; Stauffer N-3054, 10 mg. orally and 50 mg. SC; Hercules 9699, 50 mg. orally and SC; Stauffer R-3422, 50 mg. orally and 100 mg. SC; Rhodia 9895, 50 mg. orally; and Hercules 7522H, 100 mg. orally.

Screw-worm larvae surviving the screening tests of new compounds were collected and reared to adults. The adults were mated and records made of the number of eggs and percent hatch to determine if the chemicals screened produced any sterilizing effects. Of 121 compounds used in this study 13 adversely affected survival and development of larvae and pupae or oviposition and egg hatch. The most active materials and their effects were as follows: Bayer 38636 at 5 mg. orally, all male survivors; Shell 7079 at 50 mg. orally, no oviposition; Stauffer R-2404 at 10 mg. orally and SC, no hatch; ENT 5734 at 100 mg. SC, adults emerged but died without ovipositing; and Dilan at 500 mg. orally, no adult emergence from pupae.

6. House Fly. Extensive research was conducted at Orlando, Florida, on the control of the house fly in dairy barns, poultry houses, households and industrial establishments. Since the results of this research in Florida are applicable to the control of house flies affecting beef cattle, horse and swine, a brief resume of recent progress follows:

One hundred ninety-five new compounds were screened for residual effectiveness against house flies. Twenty-four materials were 90 to 100% effective for at least 24 weeks as compared with 12-16 weeks for malathion (standard). These materials included Thiodan, General Chemical GC-3583, Shell SD-4402, Upjohn TUC U-12927 (with synergist); Bayer compounds 29952, 30237, 30468 and 29492; Hooker HRS-1422, Geigy G-27365, Stauffer N-2404, heptachlor epoxide and twelve confidential compounds. Bayer 29952, Bayer 30237 and seven of the confidential compounds were still 100% effective after 44-48 weeks and are considered unusually promising for controlling flies. Several promising new compounds were evaluated as space sprays against susceptible and resistant strains of house flies. Some of the compounds were superior to malathion (standard) against susceptible flies but only one, Bayer 30911, was superior against resistant strains.

Over 50 selected compounds were evaluated as bait toxicants against resistant and normal strains of house flies. Eight of the compounds were equal or superior to Dipterex (standard) against both strains

of flies, namely: Bayer 30237, Bayer 30554, General Chemical 6506, Stauffer N-2230, Stauffer N-2404, dimethoate and two confidential compounds. All of the compounds tested were more effective against normal than against resistant flies.

Several materials which increased the effectiveness of malathion in laboratory tests were evaluated as residual treatments in barns against large populations of flies. Combinations of several synergists and malathion alone were equally ineffective in these tests.

7. Cattle Grubs and Other Bots. Research was continued in Texas, Oregon, and Nebraska to develop more effective insecticides for controlling cattle grubs and other bots affecting livestock. In Texas 131 new compounds were screened for systemic action by administering them orally and subcutaneously (SC) at several dosages to guinea pigs artifically infested with screw-worms. Ten of the materials showed systemic action in one or both types of administration. The active compounds and minimum effective dosages in mg./kg. were as follows: Stauffer N-2310, Stauffer N-2599, and Stauffer N-3055, 25 mg. orally and SC; Stauffer N-3047, 25 mg. orally; Zectran, 25 mg. orally and 50 mg. SC; Stauffer N-3054, 10 mg. orally and 50 mg. SC; Hercules 9699, 50 mg. orally and SC; Stauffer R-3422, 50 mg. orally and 100 mg. SC; Rhodia 9895, 50 mg. orally; and Hercules 7522H, 100 mg. orally.

In Texas further tests were conducted on small numbers of cattle with a number of compounds that had shown promise in screening tests or on individual cattle in 1960 and 1961 and with older effective materials administered in different ways. Ten of the new materials gave 98-100% control of grubs by one or more routes of administration. These materials, the effective doses, and routes of administration were as follows: Famophos, 25 mg./kg. intramuscularly (IM) and 10 mg./kg. in feed for 10 days; Bayer 37341, 0.5% spray, 2% pour-on, 10 mg./kg. orally, and 5 mg./kg. in feed for 10 days; Bayer 34727, 0.5% spray and 25 mg.kg. orally; Stauffer 3352, 25 mg./kg. orally; Stauffer 3828, 100 mg./kg. orally; Stauffer R-1504, 0.5% spray, 2% pour-on, 50 mg./kg. orally and 25 mg./kg. in feed for 10 days; Bayer 37342, 0.5% spray, 25 mg./kg. orally, 15 mg./kg. IM, 5 mg./kg. in feed for 10 days and 10 mg./kg. in feed for 6 days; Bayer 37289, 25 mg./kg. orally; Bayer 42,600, 25 mg./kg. orally; and Rhodia, 100 mg./kg. orally.

The older materials, dosages and routes of administration giving 98-100% control of grubs were as follows: Co-ral, 2% and 8% pour-on; Dipterex, 5 mg./kg. in feed for 10 days, 6% pour-on and 150 mg. orally; Baytex, 2.5 mg./kg. in feed for 10 days and 10 mg. IM; Butonate, 5 mg. in feed for 5 days and 10 mg. in feed for 10 days; and Ruelene, 10 mg. IM and SC. In additional tests with GC-4072 one and two sprays of 0.25% gave 94% control. Several other materials were 78-91% effective by one or more methods of administration.

Extensive field tests with government and cooperator herds of cattle were conducted in Texas, Oregon and Nebraska to evaluate the effectiveness of promising new and several older systemics at different rates and various methods of administration. In Texas 99-100% control of grubs was obtained with Co-ral at 5 mg./kg. IM and as a 4% oil solution applied to the backline by the pour-on method. Pour-on applications of 4% in oil and 2% in oil and water and 0.5% sprays were over 90% effective. Dipterex applied as a 1.5% spray and at 4% and 7.75% pour-on treatments gave 99-100% control of grubs. Ten percent pour-on applications of ronnel were 99% effective. Ruelene gave 95-100% control when applied at 2%, 4% and 7.75% by the pour-on method and as a 0.5% spray or dip. Baytex as a 1% pour-on and as a 0.25% spray gave 96 and 98% control. New materials giving 94-99% control were Bayer 37342 as a 0.5% spray and Famophos at 15 mg./kg. IM. Some of the older and newer materials failed to provide satisfactory control at lower dosages or by other methods of administration.

In Texas tests involving a number of cooperator herds were conducted to evaluate ronnel in salt blocks and as a feed supplement for the control of grubs. Feeding ronnel at the rate of 7.8 mg. daily for 14 days failed to give satisfactory control. Consumption of 2.6 to 2.8 mg./kg. daily of ronnel from the salt blocks for 4 months gave 78 to 86% control of grubs. Excellent control of 97% was indicated in herds given 7.8 mg./kg. of ronnel for 14 days and then provided with ronnel salt blocks for 3 months.

In Nebraska field tests were run to evaluate the effectiveness of Famophos as an intramuscular (IM) injection against cattle grubs. Injections of 15 mg./kg. gave 99% control as compared with 90% for 7.5 mg./kg.

In tests in Oregon with older materials, 98-100% control of grubs was obtained with the following treatments: Ruelene as 0.25 and 0.5% sprays; Dipterex as 1% and 2% sprays; Co-ral as a 0.5% spray; Baytex as a 0.25% spray, and a 25 mg./kg. in oil pour-on treatment, and in 5-day feeding tests at 5 mg./kg. Baytex also gave good but variable control at lower rates as sprays and pour-on treatments. In tests against grubs already present in the backs of cattle 85-100% kill was obtained with pour-on treatments of Baytex at 25 mg./kg. and with 2.5% dusts of DDVP and Dibrom. In tests with new materials excellent control was obtained with Bayer 37342 as a 0.25% spray and orally at 50 mg./kg. and with Famophos as a pour-on at 15 mg./kg. and in feed at 10 mg./kg. for 5 days. Bayer 37341 was highly effective as a 0.25% spray in some tests but not in others. Lower dosages of these materials and all dosages of several other new materials failed to give satisfactory control of grubs. Feeding of ronnel at the rate of 7.8 mg./kg. daily for 14 days resulted in reductions of 94-98% in grubs in several groups of cattle.

In Oregon topical application tests showed that male H. bovis adults were more tolerant of ronnel than females. The LD-100's were 180 and 100 µg/fly, respectively.

In Texas and Mississippi several of the better cattle grub systemics were evaluated against two species of horse bots. The most effective treatments were Butonate and Ruelene at 50 mg./kg. in feed; Famophos at 50 mg./kg. by stomach tube; Bayer 37341 at 50 mg./kg. by stomach tube and in feed. Tests in Mississippi indicated that dosages of 30 to 50 mg./kg. of Ruelene in feed were highly effective against horse bots but lower dosages did not give satisfactory control.

8. Horse Flies and Deer Flies. In Mississippi daily applications of synergized pyrethrins with an automatic sprayer greatly reduced the number of horse flies and deer flies attacking cattle. Sprays of insecticides, such as toxaphene, malathion and Ciodrin, were ineffective in repelling biting flies but a good percentage of those that engorged died subsequently from contact with the insecticide.

9. Lice. In Mississippi, twenty-five promising new insecticides were evaluated in spot tests in comparison with methoxychlor against cattle lice. Two materials, General Chemical 4072 and Bayer 37342, prevented reinfestation for 12 days as compared with 7 days for methoxychlor. Heavy infestations of horse lice were eradicated with 0.5% malathion sprays. Nine materials were evaluated for systemic action by giving them orally to louse-infested cattle. Co-ral caused 100% kill of all motile lice but the other materials were partially or completely ineffective at the dosages tested.

In Texas extensive field tests were run to compare the effectiveness of several of the newer insecticides against cattle lice. Sprays of 0.25% GC-4072 eradicated lice in a majority of tests but in others, light infestations developed within 2-4 weeks. Ronnel and Shell 4294 at 0.25% gave 100% immediate control but light reinfestations were apparent in all locations in 2-4 weeks. Ruelene applied at the rate of 75 mg./kg. along the backline eliminated louse infestations but lower dosages of 25 and 50 mg./kg. were not completely effective. Feeding of 50-75 mg./kg. of Ruelene over a period of 3 days reduced louse infestations only 40-50%. Daily feeding of Co-ral at 0.25 mg./kg. and Bayer 22408 at 0.5 mg./kg. for 3 weeks or more had no noticeable effect on louse infestations.

In Oregon complete control of cattle lice was obtained with sprays of 0.5% Co-ral, 0.25% Baytex and 0.75% lindane. These treatments also gave complete control of cattle scabies (Chorioptes bovis).

10. Ticks. Work on ticks was confined to the Texas laboratory. Only 4 of 131 compounds screened for systemic effectiveness showed systemic action against ticks engorging on treated guinea pigs. The effective materials, dosages (mg./kg.), and routes of administration were as follows: Rhodia, 25 mg. orally and 50 SC; Hercules 9699, 50 mg. orally and SC; Stauffer N-2310, 50 SC; and Zectran, 50 mg. orally.

Evaluation was made of the effectiveness of 71 insecticides against Boophilus ticks, using the dipping technique. A majority of the materials were toxic to this species, but the most effective were lindane, Co-ral, General Chemical 3582, General Chemical 4072, Bayer 25141, Bayer 29952, Bayer 30237, and Bayer 37341.

Extensive field tests were conducted to compare the effectiveness of several insecticides against the winter, lone star and black-legged ticks on cattle. Complete control of existing infestations of the winter and black-legged tick was obtained with sprays of 0.1% General Chemical 3582, 0.25% Shell SD-4294 and General Chemical 4072, and 0.5% methyl Baytex and toxaphene. Dilan at 0.5% and V-C 13 at 0.25% eliminated the black-legged but not the winter tick. Sprays of 0.05% diazinon and 0.5% V-C 13 gave lower immediate kills of the winter tick than 0.5% toxaphene but all three treatments were 99-100% effective after 1 week. In tests on horses, 0.25% sprays of GC-4072 and Dilan, and 0.5% sprays of toxaphene gave 100% immediate control of winter and black-legged ticks but only GC-4072 prevented reinfestation within 1 month.

Field tests indicated that 0.5% toxaphene sprays were slightly more effective against the lone star tick on cattle than any of the newer insecticides. However, excellent immediate control of this species was obtained with sprays of 0.025 and 0.05% diazinon and with 0.5% Dilan and V-C 13. In all cases light to moderate reinfestations occurred in 1-2 weeks. Feeding of ronnel at 7.8 mg./kg. daily for 14 days caused no reduction in tick populations on cattle.

In comparative tests 0.5% toxaphene emulsion applied with a Bean sprayer gave better control of winter ticks on cattle than when applied with a Spray-Foil machine. However, only 1 pint of emulsion was applied with the Spray-Foil as compared with about 1-1/2 gallons with the Bean sprayer.

C. Insecticide Residue Determinations

1. Residue Studies. Work was done in Texas and Maryland on the absorption, distribution, storage and metabolic fate of insecticides in animals using chemical and radiometric methods of analysis.

In Texas a steer given 1.88 mg./kg. orally of C^{14} phosphamidon showed peak activity in the blood in 12-18 hours, in the urine at 4 hours and in the feces at 24 hours. Little or no activity was detectible after 144 hours. Of the dose received, 71% and 5% was excreted in the urine and feces, respectively. At least 6 metabolites were found but none could be identified. Radiometric analyses did not show significant residues in muscle or fat although the method was sensitive to 1.0 part per billion.

Special tests were conducted in Texas to compare the metabolism of P^{32} Dipterex in two cows which had shown widely variable results in tests with systemics against cattle grubs. Peak activity in the blood and urine of the two animals occurred at the same time but was twice as high in one as in the other. Over a 3-day period one animal excreted nearly twice as much activity in the urine as the other. A comparison of the metabolites indicated that one animal could destroy the less polar compounds much faster than the other. These differences in the metabolism of Dipterex indicate that the effectiveness of systemics against cattle grubs may be correlated with the animal's ability to metabolize the insecticide.

Analytical methods were developed at the Texas laboratory for determining the amounts of ronnel and V-C 13 in tissues of animals that had been treated with these insecticides. The method was based on the alkaline hydrolysis of the compounds and the determination of the corresponding phenols with amino antipyrene. Analyses of fat samples from animals sprayed with 0.5% of V-C 13 showed significant residues following spraying but after 8 weeks residues ranged from 0 to 0.05 p.p.m.

In Maryland cattle fed for 104 days on apple pomace containing 103 p.p.m. of DDT accumulated large amounts of DDT in their fat. After the cattle were placed on DDT-free feed, the levels of DDT gradually decreased but after 607 days their fat still contained 8.9 p.p.m. of DDT, which is in excess of the established tolerance of 7 p.p.m.

2. Toxicity Studies. Work was conducted in Texas in cooperation with veterinarians of the Animal Disease and Parasite Research Division on the acute and chronic toxicity to livestock of insecticides and other materials applied by different routes of administration. A summary of the results are presented. Detailed results will be given under Unit 2, Animal Diseases and Parasites (ADP a7-11 and ADP a7-12). Extensive tests were run to determine the toxicity of a number of insecticides administered orally, dermally, and by intramuscular injection to cattle. In conventional spray tests with cattle, three of seven insecticides caused no symptoms of toxicity. These materials and the concentration used were Bayer 34727 at 0.25%, Stauffer R-1504 at 0.5% and Rhodia 9895 at 2.0%. One of three animals was affected by

a 0.5% application of Bayer 39193. In pour-on tests Bayer 37342 at 2.0% (125 ml.), Bayer 37342 and Bayer 34727 at 2.0% (250 ml.), and GC-4072 at 1.0% in oil (250 ml.) produced no symptoms of toxicity. GC-4072 at 1.0% in water, Bayer 37341 and Stauffer R-1504 at 2.0% affected some animals and not others. When given orally in capsules to cattle, the following materials were nontoxic: Bayer 37341 and Bayer 37289 at 10 mg./kg., Hercules 9699 at 13.4 mg., Stauffer N-3047 at 15 mg., Bayer 39193 and Stauffer N-2310 at 50 mg., and Neguvon and Rhodia 9895 at 100 mg./kg. Several other materials were toxic to some animals at the dosage tested. In similar tests with calves, 4 of 7 materials were nontoxic at low test dosages but toxic at higher dosages. No toxic symptoms were evident in cattle given 10 daily dosages of the following compounds in feed: V-C 13 at 3 mg./kg.; Neguvon at 5 mg.; GC-4072, Baytex and Stauffer R-1504 at 2.5 mg.; and Butonate and Famophos 25644 at 10 mg./kg. Butonate, Bayer 37341, Bayer 34727 and Rhodia were toxic to some animals. In additional feeding tests with horses, ENT 20738, Bayer 37341, Butonate and Ruelene were nontoxic at 50 mg./kg.

Special tests were run to determine the effects of Dibrom mist sprays as applied to the heads of cattle in controlling the face fly. Repeated applications of approximately 64 cc. of 1.25% and 24 cc. of 1.04% Dibrom produced ocular discharges in most of the animals and opaque spots on the eyes of several.

During the year a number of promising insecticides were applied at high concentrations (5-10%) with a chromatography sprayer at the rate of 100 ml. per animal. Seven compounds caused no obvious toxic symptoms but several lowered the cholinesterase (ChE) of treated animals.

D. Biological Control

In Nebraska large-scale releases of pupal parasites were initiated early in June and continued until early fall at the stockyards in Omaha and in a 36 square-mile farm area near Lincoln in an effort to control stable flies. The percent parasitism was low during the first month of releases and varied greatly (0-100%) from week to week but the average level of parasitism apparently was sufficient to keep populations at a subannoying level throughout most of the season. The parasite, Spalangia muscidarum, was most effective in dense, compact breeding habitats whereas Muscidifurax raptor was most effective near the surface of breeding sites.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Mosquitoes. In Oregon studies were conducted with a number of chemosterilants. Unfed virgin female Culex tarsalis from 1 to 6 days old did not produce eggs after being sprayed with 5% tepa. Adults

feeding on sugar containing 0.1% apholate were completely sterilized. Females produced from larvae exposed in 1 to 3 p.p.m. of tepa laid normal numbers of viable egg masses but at 10 p.p.m. very few eggs were produced and viability was less than 1%. Adults emerging from water containing 10 p.p.m. of apholate did not lay viable eggs. Female mosquitoes were sterilized by feeding on mice which had received oral doses of 10 mg./kg. of metepa or 50 mg./kg. of apholate but lower doses were not effective. Maximum effects were apparent only in adults feeding from 15-60 minutes after the mice had been treated. Studies with a radioactive chemosterilant showed that the material was rapidly absorbed and metabolized by mosquitoes and mice. Almost complete degradation occurred in 24 hours.

Other studies in Oregon were conducted to determine the effects of irradiation on various stages of Culex tarsalis. Dosages required to kill 100% of the various stages were as follows: Eggs, 800-1000 r; larvae, 150,000-180,000 r; pupae 80,000 r; and adults 100,000 r. Sterilizing doses were 5,000 r for females and at least 10,000 r for males. Doses up to 15,000 r had no effect on adult longevity but 25,000 r was definitely harmful.

Approximately 200 chemicals and other materials were tested to determine whether they would repel or attract oviposition by Culex pipiens quinquefasciatus or C. tarsalis. Several materials attracted more oviposition than distilled water but hay infusion was the most effective. A number of materials apparently were repellent and prevented oviposition by females. The most repellent materials were emulsifiers, the best of which were effective at only 2.0 p.p.m. Over 100 chemicals and other materials, including sex extracts, were evaluated as attractants for C. tarsalis and C. pipiens quinquefasciatus. None of the materials was as attractive as the carbon dioxide standard.

2. Stable Fly. In Texas a large number of chemicals was evaluated by several methods as chemosterilants against the stable fly. The most effective sterilants were apholate, tepa, metepa and crotonamide. Topical applications of 1.8-3.7 µg of apholate to newly-emerged flies had no effect on oviposition but viability was low (0-4%). Similar applications to 6-7 day old flies reduced egg viability to 2%. The sterilizing dosage was slightly less for males than for females. Flies exposed for 48 hours on residues of 10 mg./square foot of apholate on glass oviposited normally but none of the eggs hatched. The residues were effective for 22 weeks. Flies exposed for 1-hour on a residue of 100 mg./square foot of apholate were completely sterilized. Apholate and other sterilants were more effective on glass than on wood surfaces. Stable flies fed on blood containing 0.25 and 0.5% apholate and aphoxide and 0.125% metepa oviposited normally but none of the eggs hatched. Feeding of 0.05% crotonamide did affect oviposition

but only a few of the eggs hatched and none of the larvae survived to maturity. Low concentrations of 0.001 to 0.002% of these 4 sterilants in larval media had no deleterious effect on larval survival or development. Larvae dipped in concentrations of 0.1 and 0.5% survived but their development was retarded.

In Texas selected chemicals and other materials were tested as stable fly attractants. None, including sex extracts, proved attractive.

Studies were initiated in Florida and Maryland on the development of physical and mechanical methods of controlling stable flies, with particular emphasis on radiant energy. Extensive tests were conducted to develop suitable techniques for studying the response of the light and for handling the flies. The flies were equally attracted to BLB, BL and daylight fluorescent lights. The rate of attraction was not affected by changes in light intensity. Maximum response occurred near the end of the dark part of the photoperiod, indicating that a "physiological clock" may exist in flies.

3. Face Fly. In Nebraska about 200 chemicals and other materials were tested as attractants for the face fly. None of the materials was as attractive as fresh feces of cattle. Efforts to isolate and demonstrate sex attraction were unsuccessful.

Preliminary studies in Nebraska showed that aphoxide effectively sterilized the face fly. When both sexes were fed sugar containing 0.25% aphoxide for one day or 0.0025% for three days oviposition was reduced and the eggs did not hatch. Normal females mated with males fed for 3 days on 0.005% aphoxide produced only non-viable eggs.

4. Screw-worm. In Texas, where investigations on the screw-worm were conducted, over 250 compounds were screened as chemosterilants by several methods against various stages of the insect. About 50 of the materials caused complete sterility by one or more methods of test. Nearly all of the effective sterilants were confidential materials which cannot be identified by name or structure at this time. Known materials causing complete sterility were: Apholate, tepa, tretamine and metepa, applied topically and in adult food; colchicine, 2,6-diaminopurine and morzid, in food; and methiotepa and Thiotepa, applied topically. One material (confidential) was effective as a sterilant in the larval media but was ineffective by other means of application. Some of the active materials sterilized either sex, others were effective only when both sexes were treated, and others were effective only on one sex. Tretamine and a number of other materials sterilized all ages of flies but some materials were effective only against newly-emerged flies.

Tests indicated that there was no consistent difference in the effects of 1,000 and 5,000 r administered as a single dose or two equal doses. Female flies 3, 4, and 5 days old differed greatly in radiation sensitivity but dominant lethals were induced in the oocytes of all ages. In additional tests with 5-day-old pupae, which have only oogonial cells, the number of eggs deposited by females decreased as the radiation dose increased, indicating that damage to some cells eliminated them from the germ line and that they were not rapidly replaced.

Over 200 chemicals and other materials were screened for attractiveness to the screw-worm fly by special olfactometer procedures and by exposing them in beakers in cages of flies. In olfactometer tests isovaleraldehyde was 10 times as attractive as liver (standard) but was less attractive than liver in beaker tests. Several additional materials were as attractive as liver but none was superior. Studies with liver and other materials indicated that light increased attractiveness and that maximum attraction occurred at 95°-106° F. Materials exposed at 86°-113° attracted 2-3 times as many flies as when exposed at 67°-80°. Very few flies from 1 to 3 days responded to attractants. Highest attraction occurred when flies were 3-4 days old.

5. House Fly. Studies in Oregon indicated that irradiation of resistant house flies with sub-sterilizing doses of 1,000 r did not alter their susceptibility to insecticides or esterase activity. Treated females mated with untreated males oviposited normally but only 45% of the eggs hatched. Additional studies were conducted with normal and parathion-resistant flies that had been irradiated as puape with 600 r for seven generations. Only about 25% of the eggs hatched from matings of irradiated males and females of either colony. No changes in insecticide susceptibility or esterase activity were apparent.

Extensive research on sterilization, attractants and other new approaches to control of the house fly was conducted at Orlando, Fla., in connection with the control of the house fly in dairy barns, poultry houses, households and industrial establishments. Since the results of this research is applicable to the control of house flies in other situations, some of the highlights of recent research at that laboratory follows.

Irradiation caused greater damage to early (2-4 days old) house fly pupae than to middle-age pupae. Virtually no damage was apparent in old pupae and longevity of adults was greater than that of younger pupae. Irradiation of pupae 0-36 hours before adult emergence did not produce complete sterility and some recovery was indicated since second matings resulted in a slight increase in progeny. No recovery occurred in pupae irradiated 72-96 hours before adult emergence.

Extensive studies were conducted to find materials that will induce sterility or otherwise affect the growth and development of the house

fly. Of about 1300 compounds tested in the adult food, 21 caused sterility in flies. Only one of about 800 materials tested in the larval media caused sterility but nearly one-third were toxic to the larvae. In secondary tests with 59 compounds that had shown promise in screening tests, twenty-seven caused sterility (no oviposition or hatch) at concentrations of 1% or lower. Additional tests were run with 50 promising materials applied as larval dips, topically to adults, and in the adult food. None caused sterility as larval dips but in adult food, six induced complete or nearly complete sterility. Two other materials were effective only as topical applications.

Special tests were run with 24 promising chemosterilants to ascertain the effects of each sex. Only one material, an aziridinyl compound, caused sterility in both sexes. Methiotepa, 5-fluoroacetic acid, metepa and a confidential material caused complete sterility in males but not always in females. Three materials, 5-fluoroacetic acid, an aziridinyl compound, and 5-fluorouracil, were effective when fed to both sexes.

Studies were conducted to learn more about the action of several effective chemosterilants on house fly sexual development, mating and reproduction. In one series of tests, males sterilized by feeding 3 days on apholate proved fully competitive with normal males when placed with normal females. When only treated males were placed with normal females all eggs were sterile and 12.5% were sterile when only normal males were present. When normal females, normal males, and treated males were combined at ratios of 1:1:1 and 1:1:2, 65 and 80% of the eggs were sterile and higher ratios of 1:1:3, 1:1:5, and 1:1:10 resulted in 99.9 to 100% sterility. Additional tests at these ratios confirmed that actual sterility was higher than expected. Males given food containing 0.4 to 1.0% apholate for 3 days were sterilized for life but lower concentrations of 0.1 to 0.3% were not 100% effective. Exposures of males on residues of 500-1,000 mg./kg. of tepa on plywood panels caused only partial sterility (12-72%) but when applied at 250-500 mg./square foot with sugar tepa and apholate produced 91-100 and 99-100% sterility, respectively. When applied in glass jars, residues of 250 mg./square foot of tepa or metepa completely sterilized flies in 2-4 hour exposures for 30 days but not for 60. Deposits of 100 and 50 mg./square foot caused complete sterility for 14-30 and 14 days, respectively, but deposits of 10-25 mg. were mostly ineffective. Baits containing 0.5% of tepa and metepa effectively sterilized flies after aging 30-37 days on most types of surfaces. Some loss in effectiveness in tepa was apparent on metal and masonite and in metepa on wood but none was apparent on painted wood, asphalt, metal or wax paper.

Weekly applications of cornmeal bait containing 0.5% tepa on an isolated refuse dump reduced adult house fly populations from 47 to 0 per grid count in 4 weeks and counts remained at 0 as long as the

bait was distributed. The viability of eggs of female flies declined from 100 to 10% in 4 weeks and to 1% in 5 weeks. After baiting ceased, populations increased slowly but the percent viability of eggs was normal after 2 weeks. Additional small-scale field tests with cornmeal-chemosterilant baits against flies were conducted on a small garbage dump and in a poultry house. Weekly applications of apholate baits on the dump and of metepa baits in the poultry houses caused some sterility and reduction of fly populations. Applications 5 days a week resulted in a high degree of control and high sterility in flies in both areas. Sterility among females was slightly higher than in males.

Comparative tests showed slight differences in the competitive ability of male flies given 1% apholate in food and those irradiated with 2,850 r. Neither radiation nor the apholate completely sterilized the males but at a 4:1:1 ratio chemosterilized males caused a reduction in egg hatch of 81.4% as compared with 78% for the irradiated males.

6. Ticks. Preliminary tests were conducted in Texas to study the effects of several known chemosterilants on tick molting, longevity, and reproduction. Engorged lone star tick larvae dipped in 1.0% apholate molted to nymphs and then to adults but those dipped in 0.5% tepa, tretamine and metepa failed to molt to nymphs. In similar tests in which engorged nymphs were dipped in 0.5% solutions the percentages molting were as follows: Apholate, 45%; tepa, 70%; and tretamine and metepa, zero. All unfed female ticks dipped in 1.0% solutions of these four materials failed to engorge. From 40-60% of those dipped in 0.5% solutions engorged but data are not yet available on the sterilizing effects of the materials. The females dipped in apholate required 15.5 days to engorge but those dipped in other materials engorged in about the same time (11.2 days) as control females.

Studies in Texas indicated that irradiation at the rate of 1,000 r had no effect on the molting of unfed or engorged nymphal lone star ticks. However, a dose of 2,500 r prevented molting of unfed and 1-day engorged ticks and only 3% of those engorged 1 week molted to adults.

F. Evaluation of Equipment for Insect Detection and Control

1. Sprayers. In Texas, in cooperation with the Agricultural Engineering Research Division, one series of tests was conducted to compare the efficiency of a conventional (Bean) sprayer with that of a Spray-Foil sprayer in applying insecticides to cattle. The Spray-Foil machine gave slightly less control of ticks than the conventional sprayer. However, the Spray-Foil machine applied only one-tenth as much spray per cow as the conventional sprayer. With an increase of two-fold in output the Spray-Foil machine would probably give as good results as the conventional sprayer.

2. Mechanical Devices. In Maryland studies were initiated to evaluate available models of light traps, insect electrocutors and other mechanical devices for the control of flies and other insects. Primary emphasis has been given to comparing the attractiveness of different kinds of light and different intensities. Special test chambers were developed for this purpose. None of the devices tested proved highly attractive or effective. Further tests of existing equipment and efforts to develop more efficient traps and other devices are in progress in cooperation with the Agricultural Engineering and Animal Husbandry Research Divisions of ARS.

G. Insect Vectors of Diseases

1. Anaplasmosis. Studies were continued in Mississippi, Texas and Oregon in an effort to correlate the presence and abundance of insects and ticks with the incidence of anaplasmosis in herds of cattle. These studies were conducted in cooperation with the Animal Disease and Parasite Research Division and veterinarians of the various State Experiment Stations. In Mississippi, daily applications of synergized pyrethrins sprays (0.05% pyrethrins + 0.5% synergist) with an automatic sprayer gave complete control of horn flies and significantly reduced attacks by horse flies. The effectiveness of the spray was reflected in a very low incidence (4 cases) of anaplasmosis in the treated herd as compared with that (18 cases) in the control herd. The 4 cases in the treated herd were mild, whereas there were a number of acute cases in the control herd and two animals died. The fact that first transmission in the treated herd did not occur for two months after the first case developed in the control herd serves as a further indication of the effectiveness of the sprays in protecting animals from biting flies. In another test, daily feeding of aureomycin at the rate of 0.5 mg. per pound of body weight reduced the transmission of anaplasmosis even though no effort was made to control biting flies. Only 4 cases of the disease developed in the antibotic herd compared with 11 in the control herd. The first case in the treated herd did not occur for over two months after the first one in the control herd.

In Texas monthly surveys were continued to determine the identity and abundance of external parasites on infected (anaplasmosis) and isolated clean herds of cattle. Small numbers of lone star ticks, ear and black-legged ticks and moderate numbers of the winter tick were present on cattle in January. Populations of the lone star tick increased steadily during February and March, but populations of other ticks were low. First horn flies appeared in March. During April, May, June and July, cattle were heavily infested with the lone star ticks and horn flies and with small to moderate numbers of ear ticks. Populations of all these species were low during August and September. In October the winter, ear and black-legged ticks and horn flies and grubs were

present in small numbers. Moderate to high populations of the winter and ear ticks and grubs and small numbers of black-legged ticks were noted during November and December but no flies were observed on the cattle. No transmission of anaplasmosis has occurred in the isolated clean herds although no effort has been made to control potential insect and tick vectors.

The Oregon station continued surveys in Wyoming from spring to fall to determine the distribution, abundance and seasonal occurrence of potential arthropod vectors of anaplasmosis on several experimental herds of cattle on the Myers' Ranch. The tick, Dermacentor andersoni, a known vector of anaplasmosis, appeared early in the spring, reached a peak population in May, declined gradually thereafter, and virtually disappeared by August. Light to moderate populations of several species of lice were present on cattle throughout the season. Horn flies and numerous species of mosquitoes were present in small to large numbers from May until the advent of cool weather. About 12 species of horse flies and deer flies were present in small numbers throughout the summer. Negative susceptible cattle have developed very few cases of anaplasmosis despite the presence of ticks and other vectors. It therefore appears that natural transmission of anaplasmosis rarely occurs under the Myers' Ranch conditions.

Studies were continued at Beltsville, Md., on the transmission of bovine anaplasmosis. Further attempts to demonstrate transovarian passage of the anaplasma agent in Dermacentor andersoni were negative When unmated males were forced into hibernation, the survivors readily transmitted the disease 6 months and 3 weeks after engorging on infected cattle. The unmated males survived longer than mated males under hibernation and normal colony conditions. None of the mated males survived hibernating conditions. A series of D. andersoni specimens taken from cattle in the experimental areas on the Myers' Ranch in Wyoming were tested on splenectonized calves. None of the ticks transmitted anaplasmosis.

Progress was made in studies on the anaplasmosis organism in ticks, using fluorescent antibody, electron microscopy, and conventional staining and histological techniques. Structures believed to be the projection part of the organism were demonstrated in the gut and feces smears by the fluorescent antibody technique. These structures were also found by electron microscopy in feces smears.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Biology, Physiology, and Nutrition

Bigley, W. S. and Plapp, F. W. 1961. Esterase activity and susceptibility to parathion at different stages in the life cycle of phosphate-resistant and susceptible flies. Jour. Econ. Ent. 54(5), pp. 904-907.

Chapman, H. C. 1961. Observations on the snow mosquitoes in Nevada. Mosq. News 21(2), pp. 88-92.

Chapman, H. C. 1961. Additional records and observations on Nevada mosquitoes. Mosq. News 21(2), pp. 136-138.

Chapman, H. C. 1961. Abandoned mines as overwintering sites for mosquitoes, especially Culex tarsalis Coq., in Nevada. Mosq. News 21(4), pp. 324-327.

Chapman, H. C. 1962. The bio-ecology of Culex erythrothorax Dyar. Mosq. News 22(2), pp. 130-134.

Chapman, H. C. 1962. A survey for autogeny in some Nevada mosquitoes. Mosq. News 22(2), pp. 134-136.

Drummond, R. O. and Chamberlain, W. F. 1961. Studies on respiration of cattle grubs. Annals Ent. Soc. of Amer. 54(4), pp. 524-526.

LaBrecque, G. C. and Wilson, H. G. 1961. Development of insecticide resistance in three field strains of house flies. Jour. Econ. Ent. 54(6), pp. 1257-1258.

LaBrecque, G. C., Meifert, D. W. and Smith, C. N. 1962. Mating competitiveness of chemosterilized and normal male house flies. Science 136(3514), pp. 388-389.

LaChance, L. E. and Hopkins, D. E. 1962. Mutations in the screw-worm fly. Jour. Econ. Ent. 55(4)

Morgan, P. B. and LaBrecque, G. C. 1962. Studies on the effect of apholate on ovarian development of house flies. Jour. Econ. Ent. 55(4)

Plapp, F. W. and Bigley, W. S. 1961. Inhibition of house fly ali-esterase and cholinesterase under in vivo conditions by parathion and malathion. Jour. Econ. Ent. 54(1), pp. 103-108.

Plapp, F. W., Bigley, W. S., Darrow, D. I., and Eddy, G. W. 1961. Studies on parathion metabolism in normal and parathion-resistant house flies. Jour. Econ. Ent. 54(2), pp. 389-392.

Plapp, F. W. and Bigley, W. S. 1961. Carbamate insecticides and ali-esterase activity in insects. Jour. Econ. Ent. 54(4), pp. 793-796.

Plapp, F. W., Borgard, D. E., Darrow, D. I., and Eddy, G. W. 1961. Studies on the inheritance of resistance to DDT and to malathion in the mosquito Culex tarsalis Coq. Mosq. News 21(4), pp. 315-319.

Plapp, F. W. and Eddy, G. W. 1961. Synergism of malathion against resistant insects. Science 134(3495), pp. 2043-2044.
Roberts, R. H. 1962. Notes on the biology of Tabanus dorsifer Walker (Tabanidae: Diptera). Annals Ent. Soc. Amer. 55(4), pp. 436-438.

Insecticidal and Sanitation Control

Anthony, D. W., Hooven, N. W., and Bodenstein, O. 1961. Toxicity to face fly and house fly larvae of feces from insecticide-fed cattle. Jour. Econ. Ent. 54(3), pp. 406-408.
Chapman, H. C. 1962. Laboratory evaluation of materials as larvicides against mosquitoes in Nevada. Mosq. News 22(1), pp. 24-26.
Davis, A. N. and Gahan, J. B. 1961. New insecticides for the control of salt-marsh mosquitoes. Fla. Ent. 44(1), pp. 11-14.
Davis, A. N. and Gahan, J. B. 1961. Wind-tunnel tests with promising insecticides against adult salt-marsh mosquitoes, Aedes taeniorhnchus (Wied.). Mosq. News 21(4), pp. 300-303.
Drummond, R. O. 1961. Compounds screened as animal systemic insecticides at Kerrville, Texas, 1953-1960. ARS 33-64.
Drummond, R. O. 1961. Tests with sprays of General Chemical 4072 for systemic control of cattle grubs. Jour. Econ. Ent. 54(5), pp. 1047.
Drummond, R. O. 1961. Tests with General Chemical 3582 and 4072 for the control of ticks affecting livestock. Jour. Econ. Ent. 54(5), pp. 1050-1051.
Drummond, R. O. and Graham, O. H. 1962. Low-volume dermal applications and injections of Co-ral for systemic control of cattle grubs. Jour. Econ. Ent. 55(2), pp. 255-258.
Drummond, R. O. 1962. Further evaluation of animal systemic insecticides in 1961. Jour. Econ. Ent. 55(3), pp. 398-402.
Eddy, G. W. 1961. Laboratory tests of residues of organophosphorus compounds against house flies. Jour. Econ. Ent. 54(2), pp. 386-388.
Eddy, G. W. and Roth, A. R. 1961. Toxicity to fly larvae of the feces of insecticide-fed cattle. Jour. Econ. Ent. 54(3), pp. 408-411.
Gahan, J. B., LaBrecque, G. C., and Wilson, H. G. 1961. Hercules AC-5727 as a residual spray for adult mosquitoes. Jour. Econ. Ent. 54(1), pp. 63-67.
Gahan, J. B., LaBrecque, G. C., and Wilson, H. G. 1961. Residual toxicity of some new insecticides to adults of Anopheles quadrimaculatus Say. Mosq. News 21(4), pp.289-294.
Graham, O. H. 1961. The primary evaluation of three organophosphorus compounds for possible use in the control of livestock insects. Jour. Econ. Ent. 54(5), pp. 1046-1047.
Hoffman, R. A. and Drummond, R. O. 1961. Control of lice on livestock and poultry with General Chemical 4072. Jour. Econ. Ent. 54(5), pp. 1052-1053.

LaBrecque, G. C., Gahan, J. B., and Wilson, H. G. 1961. Relative susceptibility of four species of mosquitoes to insecticide residues. Fla. Ent. 44(4), pp. 185-188.

Lewis, L. F. and Eddy, G. W. 1961. Laboratory evaluation of insecticides against the adult horn fly. Jour. Econ. Ent. 54(2), pp. 392-393.

McDuffie, W. C. 1961. Present status and future of control of insect pests of dairy cattle. Proc. 54th Ann. Conv. Milk Ind. Found. (Wash., D. C.), pp. 20-28.

Medley, J. G. and Drummond, R. O. 1962. Polymerization a means of prolonging effectiveness of orally administered systemic insecticides. Jour. Econt.Ent. 55(1), pp. 118-121.

Roberts, R. H., Wrich, M. J., Hoffman, R. A., and Jones, C. M. 1961. Control of horn flies and stable flies with three General Chemical compounds. Jour. Econ. Ent. 54(5), pp. 1047-1049.

Roth, A. R. and Eddy, G. W. 1961. Results of field tests with new cattle grub systemics. Jour. Econ. Ent. 54(1), pp. 203-204.

Schmidt, C. H. and Weidhaas, D. E. 1961. The toxicological action of three organophosphorus insecticides with three species of mosquito larvae. Jour. Econ. Ent. 54(3), pp. 583-586.

Wrich, M. J. 1961. A comparison of Co-ral, ronnel and Ruelene dusts for screwworm control. Jour. Econ. Ent. 54(5), pp. 941-945.

Wrich, M. J., Chamberlain, W. F., and Smith, C. L. 1961. Toxicity of General Chemical compounds 3582, 3583, and 4072 to screwworms in laboratory and field tests. Jour. Econ. Ent. 54(5), pp. 1049-1050.

Insecticide Residue Determinations

Bovard, K. P., Priode, B. M., Whitmore, G. E., and Ackerman, A. J. 1961. DDT residues in the internal fat of beef cattle fed contaminated apple pomace. Jour. Animal Science 20(4), pp. 824-826.

Chamberlain, W. F. and Hopkins, D. E. 1962. Absorption and elimination of General Chemical 4072 applied dermally to cattle. Jour. Econ. Ent. 55(1), pp. 86-88.

Gatterdam, P. E., Chamberlain, W. F.,and Hopkins, D. E. 1962. Studies with P^{32} labeled Bayer 22408 in steers and guinea pigs. Jour. Econ. Ent. 55(3), pp. 326-331.

Ivey, M. C., Claborn, H. V., Mann, H. D., Radeleff, R. D., and Woodard, G. T. 1961. Aldrin and Dieldrin content of body tissues of livestock receiving aldrin in their diet. Jour. Agric. and Food Chem. 9(5), pp. 374-376.

Ivey, M. C., Roberts, R. H., Mann, H. D., and Claborn, H. V. 1961. Lindane residues in chickens and eggs following poultry house sprays. Jour. Econ. Ent. 54(3), pp. 487-488.

Roberts, R. H., Radeleff, R. D., and Claborn, H. V. 1961. Residues in the milk of dairy cows sprayed with P^{32} labeled General Chemical 4072. Jour. Econ. Ent. 54(5), pp. 1053-1054.

Insect Sterility, Attractants and Other New Approaches to Control

Chamberlain, W. F. 1962. Chemical sterilization of the screwworm. Jour. Econ. Ent. 55(2), pp. 240-248.

LaBrecque, G. C. 1961. Studies with three alkylating agents as house fly sterilants. Jour. Econ. Ent. 54(4), pp. 684-689.

Lindquist, A. W. 1961. Chemicals to sterilize insects. Jour. Wash. Acad. Science 51(7), pp. 109-114.

Lindquist, A. W. 1961. New ways to control insects. Pest Control 29(6), pp. 9, 11-12, 14, 16, 18-19, 36, 38, 40.

Weidhaas, D. E., Ford, H. R., Gahan, J. B., and Smith, C. N. 1962. Preliminary observations on chemosterilization of mosquitoes. Proc. N. J. Mosq. Ext. Assoc. (1961) pp. 106-109.

Weidhaas, D. E., Schmidt, C. H., and Chamberlain, W. F. 1962. Research on radiation in insect control. Proc. Symposium on Radioisotopes and Radiation in Entomology, Bombay, India (Dec. 5-9, 1960), pp. 257-265, International Atomic Energy Agency.

Wilson, H. G., LaBrecque, G. C., and Gahan, J. B. 1961. Laboratory tests of selected house fly repellents. Fla. Ent. 44(3), pp. 123-124.

Insect Vectors of Diseases

Anthony, D. W. 1962. Tabanidae as disease vectors. Biological Transmission of Disease Agents (Academic Press) pp. 93-107.

Collins, J. C., Scales, J. W., Hoffman, R. A., and Roberts, R. H. 1962. The control of anaplasmosis by aureomycin feeding. Miss. Farm. Res. Jour. 25(5), pp. 1-2.

Hoffman, R. H., Smith, K. O., Collins, J. C., and Mott. L. O. 1961. Insect control can reduce spread of anaplasmosis. Miss. Farm. Res. Jour. 24(4), pp. 1,5.